Atlantic Hurricane Season of 1995

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ABSTRACT

The 1995 Atlantic hurricane season is described. There were eight tropical storms and 11 hurricanes for a total of 19 named tropical cyclones in the Atlantic basin during 1995. This is the second-largest number of tropical storms and hurricanes in over 100 years of records. Thirteen named tropical cyclones affected land.

1. Introduction

This report continues a tradition of *Monthly Weather Review* annual summaries of Atlantic basin tropical cyclone activity that goes back to the year 1881. An overview of the season is given in section 2. Section 3 is a mostly chronological description of the track and intensity of each tropical storm and hurricane in the Atlantic Ocean, Caribbean Sea, or Gulf of Mexico during 1995. Individual storm descriptions are subdivided into 1) synoptic history, 2) meteorological statistics, and 3) casualties and damage, when appropriate. Section 4 is a brief summary of error statistics of National Hurricane Center (NHC) official track and intensity forecasts.

The data used to track tropical cyclones consist primarily of 1) satellite imagery; 2) aircraft reconnaissance data; 3) conventional surface and upper-air meteorological observations, including ship reports; and 4) radar. Aircraft reconnaissance is accomplished primarily by the U.S. Air Force Reserve Unit ''Hurricane Hunters'' from Keesler Air Force Base in Biloxi, Mississippi. National Oceanic and Atmospheric Administration (NOAA) research aircraft are sometimes used to supplement the Hurricane Hunters. Reconnaissance is ordinarily used when a tropical cyclone is west of 55°W or in a position to threaten land. Tropical cyclones located east of this longitude are monitored only by satellite and a few island observations. When a tropical cyclone is within the several-hundred-kilometer range of land-based radar, this network of observing tools is invaluable.

Tracking the center or eye of a tropical cyclone is relatively straightforward. Except for weak systems, the center is a well-defined, mostly cloud-free area of light winds and lowest surface pressure. It is reliably located from both satellite and aircraft data. The intensity is more difficult to determine, as it is defined as the maximum 1-min surface (10 m) wind speed, anywhere within the tropical cyclone circulation.

The location of the maximum wind speed could be anywhere within 50 km or more from the center, so that a rather large area is involved. Aircraft generally make two perpendicular passes through the cyclone, sampling the flight level wind as often as every 10 s, but this leaves much of the area not sampled. Also the aircraft flight level ranges from about 450 m to 3 km, and estimating the surface wind speed from observations at these altitudes introduces uncertainty. An adjustment factor of 0.8 is often used to reduce wind speeds from flight level, but this value can vary from about 0.5 over northern latitudes during stable conditions to 1.0 or higher in an eyewall in the deep Tropics. This subject is addressed by Powell and Houston (1998). The Hurricane Research Division of NOAA has recently developed a semiobjective analysis scheme that provides a first guess of the surface wind field, using all available data.

Estimates derived from satellite data of the maximum 1-min surface wind speed of a tropical cyclone are based on the Dvorak (1984) method. These remote measurements are also a source of uncertainty. Satellite intensity estimates, along with a position ''fix'' of the circulation center, are made every 6 h from geostationary satellite imagery by the Tropical Analysis and Forecast Branch of the Tropical Prediction Center and by the Synoptic Analysis Branch of the National Environmental Satellite, Data and Information Service. Similar estimates are made from polar-orbiting satellites approximately twice per day by the U.S. Air Force Global Weather Central.

The National Weather Service (NWS) classifies tropical cyclones according to the maximum 1-min surface wind speed. The tropical depression stage is for a max-

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imum wind speed less than 17.5 m s^{-1} (34 kt); tropical storm stage is 17.5–32.4 m s^{-1} (34–63 kt); hurricane stage is 32.9 m s^{-1} (64 kt) or greater. The Saffir–Simpson hurricane scale (Simpson and Riehl 1981) is also widely used to give an indication of the intensity. The categories for this scale are defined by wind speed as follows: category 1: 32.9–42.5 m s^{-1} (74–95 mph), category 2: 42.9–49.2 m s^{-1} (96–110 mph), category 3: 49.6–58.1 m s^{-1} (111–130 mph), category 4: 58.6–69.3 m s^{-1} (131–155 mph), category 5: greater than 69.3 m s^{-1} (155 mph). Minimum sea level pressure and storm surge height are also used to define the Saffir–Simpson scale, but only when the wind speed is not adequately known.

2. Overview of the hurricane season

Figure 1 shows the tracks of this season's 19 named tropical cyclones of which 11 became hurricanes. Table 1 is a listing of storm name, dates, minimum central surface pressure, maximum 1-min surface wind speed, death totals, and total dollar damage. The tracks in Fig. 1 are based on ''best track'' statistics, which are determined at the NHC after consideration of all available data. The best track is a table of latitude and longitude, or position, of the tropical cyclone center, central pressure, and maximum wind speed every 6 h. It is possible that the maximum wind speed during a tropical cyclone's duration can occur between the 6-h times of the best track data. For example, Hurricane Erin's highest wind speed of 44 m s^{-1} occurred at 1330 UTC 3 August during landfall near Fort Walton Beach, Florida, whereas the best track for Erin shows a maximum wind speed of 41 m s^{-1} at 1200 UTC. An additonal source of uncertainty of the wind speed is a result of the fact that the wind speed values in Table 1 were originally compiled in units of knots and rounded off to the nearest 5 kt before being converted to meters per second. It would be difficult to quantify the uncertainty of the wind speed estimates in Table 1 and throughout this paper.

The number of tropical storms and hurricanes, by year, is given by Neumann et al. (1993). Since the year 1871, this year's 19 tropical storms and hurricanes is second in number only to the year 1933 (21 tropical storms and hurricanes). This year's 11 hurricanes were exceeded in 1969 (12 hurricanes) and tied in 1916 and 1950. Also, the previous 50-yr average is for 9.6 tropical storms, of which 5.6 become hurricanes. There are other measures of a hurricane season's activity. Landsea et al. (1998) have compiled an index of seasonal activity since 1950. This season's index is the second largest during this 46-yr period.

Such an anomalously active year is expected to be accompanied by strong ''signals'' from parameters that have been causally related to hurricanes. One such parameter is the vertical shear in the horizontal wind, which when large enough, can disrupt the energetic processes that maintain a storm's intensity. Landsea et al. (1998) review the environmental conditions of the 1995 season. They show an August–October 1995 anomaly field of the magnitude of the vertical wind shear between the upper-level and lower-level winds. There are negative anomalies across the tropical Atlantic Ocean, the Caribbean Sea, and the southern Gulf of Mexico. Negative values of up to 7 m s^{-1} are found in the central Caribbean area.

A feature of this season's tracks is the many tropical cyclones that recurved across the North Atlantic. It is speculated that there should be a corresponding weakness in the western North Atlantic subtropical high pressure ridge and, indeed, Landsea et al. (1998) show a weak 500-mb trough (and negative 500-mb height anomalies) over the western North Atlantic Ocean for the August–October 1995 mean fields.

Some of the season highlights include the following. The origins of 17 of the year's storms and hurricanes were attributable to tropical waves that moved from western Africa into the eastern Atlantic Ocean. Only Tropical Storms Barry and Dean did not originate from tropical waves. There were five tropical cyclones on going at the same time in the Atlantic basin on 27 and 28 August. A total of 123 deaths were estimated to have been caused by tropical storms and hurricanes this year. Damages from Hurricane Opal are estimated at $3 billion in the Florida panhandle and across the southeastern United States. Hurricane Luis caused an estimated $2.5 billion in damage to the northeastern Leeward Islands of the Caribbean and Hurricane Marilyn caused $1.5 billion in damage in the northeastern Caribbean, primarily to the U.S. Virgin Islands.

3. Description of individual named tropical cyclones

a. *Hurricane Allison, 3–6 June*

Allison was an early season hurricane that formed over the northwest Caribbean Sea. It weakened to slightly below hurricane strength just before making landfall in north Florida. Allison was responsible for one death in western Cuba.

1) SYNOPTIC HISTORY

Satellite images and rawinsonde data show that a tropical wave passed over the Windward Islands on 28 May. When the wave entered the western Caribbean Sea on 1 June, it was accompanied by a broad midlevel cyclonic circulation, which rawinsonde observations indicated was particularly distinct at the 700-mb level. Convective cloudiness acquired sufficient organization to warrant an initial Dvorak satellite classification at 0000 UTC 2 June. At that time, the cloud cluster was located several hundred km to the east of Honduras. The system moved north-northwestward and gradually became better organized during the daylight hours of 2 June. The first

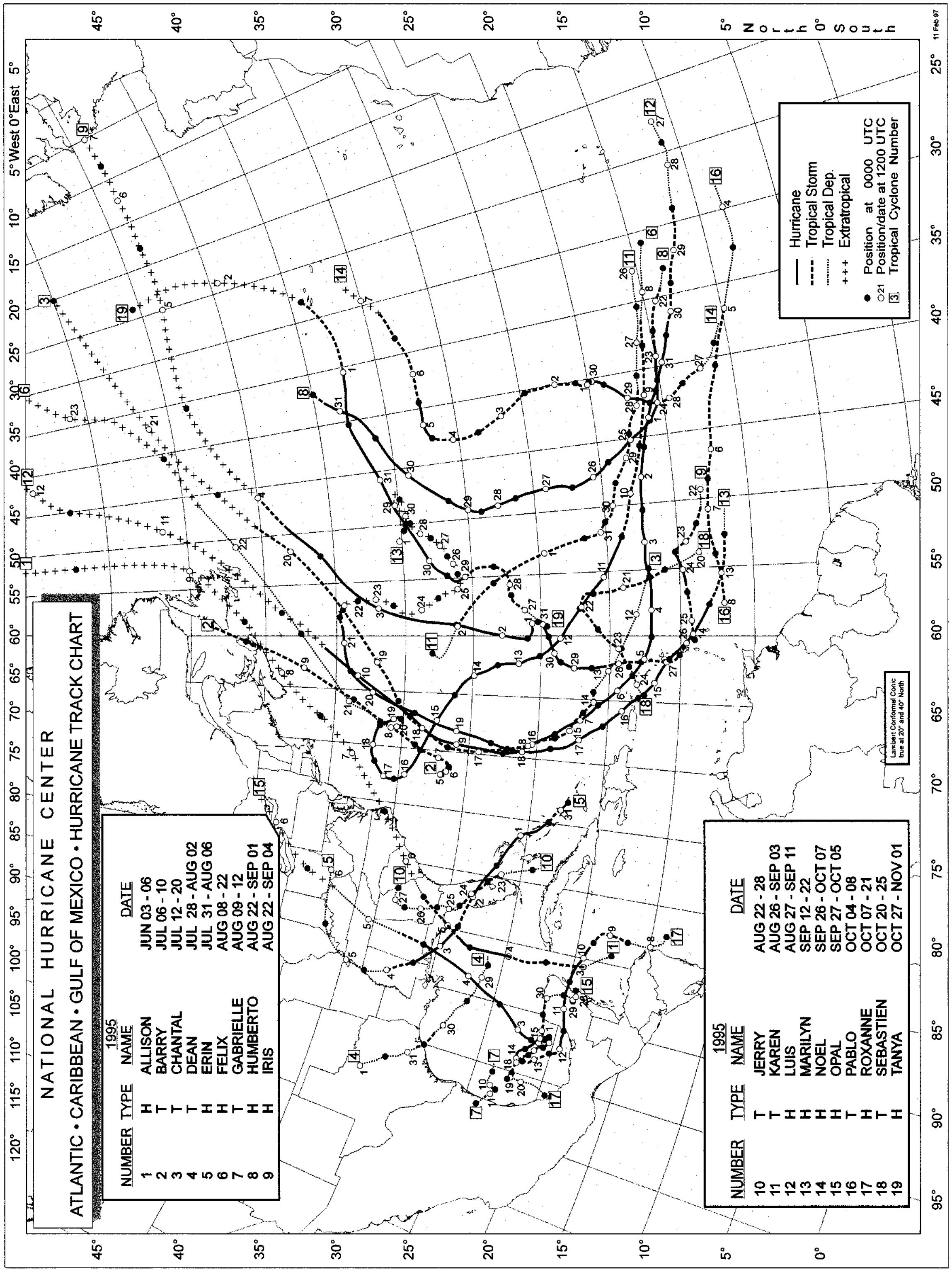

FIG. 1. Tropical storm and hurricane tracks for 1995.

TABLE 1. Atlantic basin tropical storms and hurricanes, 1995.

	Name	Tropical cyclone dates	Min press. (mb)	Max wind speed (m s^{-1})	Deaths	U.S. damages
1	Allison	3–6 Jun	987	33	3	\$1.7M
2	Barry	6–10 Jul	989	31		
3	Chantal	12–20 Jul	991	31		
4	Dean	28 Jul–2 Aug	999	21		\$500,000
5	Erin	31 Jul–6 Aug	973	44	6	\$700M
6	Felix	8–22 Aug	929	62	8	
7	Gabrielle	9–12 Aug	988	31		
8	Humberto	22 Aug–1 Sep	968	49		
9	Iris	22 Aug–4 Sep	965	49	3	
10	Jerry	22–28 Aug	1002	18	6	>\$27M
11	Karen	26 Aug–3 Sep	1000	23		
12	Luis	27 Aug–11 Sep	935	62	16	*
13	Marilyn	12–22 Sep	949	51	8	\$1.5B
14	Noel	26 Sep–7 Oct	987	33		
15	Opal	27 Sep–5 Oct	916	67	59	\$3B**
16	Pablo	4–8 Oct	994	26		
17	Roxanne	7–21 Oct	956	51	14	**
18	Sebastien	20–25 Oct	1001	28		
19	Tanya	27 Oct–1 Nov	972	39		

* \$2.5B non–United States damage.
** \$1.5B combined damage in Mexico from Opal and Roxanne.

reconnaissance flight into the area revealed that the system became a tropical depression around 0000 UTC on 3 June, centered 425 km east of Belize City.

Continuing on its north-northwestward heading, the depression strengthened into Tropical Storm Allison at 1200 UTC 3 June. The intensifying storm turned northward and moved through the Yucatan Channel. The storm deepened even though southwesterly upper-level winds were creating a vertical shearing environment. In fact, by 1200 UTC 4 June, Allison became a 33 m s^{-1} hurricane over the southeast Gulf of Mexico, centered 445 km west of Key West. However, the strengthening trend ended and Allison never developed beyond a minimal hurricane. Moving northward at a forward speed of near 8 m s^{-1}, Allison headed for the Florida panhandle.

Early on 5 June, as the system drew nearer to the coast, it turned northeastward and weakened slightly, apparently in response to south-southwesterly vertical shear. Allison's winds dropped just below hurricane force by 0600 UTC 5 June. Landfall occurred at 1400 UTC 5 June on the coast of north Florida, near Alligator Point, and again (after a very brief time over water) at 1500 UTC near Saint Marks. Maximum winds at landfall are estimated at 28–31 m s^{-1}. The storm weakened further as it headed inland to Georgia, but tropical storm force winds persisted over Apalachee Bay until 2100 UTC 5 June. Allison diminished to a tropical depression over southern Georgia by 0000 UTC 6 June.

By 0600 UTC 6 June, the system acquired extratropical characteristics as it interacted with a warm frontal zone to the northeast. Gale force winds developed along the Georgia and South Carolina coasts as the cyclone's isobaric pattern expanded and the pressure gradient increased well east of the low center. During the day, the low moved northeastward over the coastal plain of the southeastern United States, emerging into the Atlantic a little north of Cape Hatteras just after 0000 UTC 7 June. The low, with an associated area of gale to storm force winds over its southeastern semicircle, moved rapidly northeastward, skirting the eastern shore of Nova Scotia on 8 June, as it headed for Newfoundland. After passing over Newfoundland on 9 June, the gale center turned northward, and then north-northwestward, crossing the Arctic Circle to the west of Greenland on 11 June.

2) METEOROLOGICAL STATISTICS

The maximum wind speed recorded in Allison was 38 m s^{-1} at 700 mb from a U.S. Air Force reconnaissance plane at 0019 UTC 5 June, and the lowest surface pressure, 987 mb, was measured at 1346, 1527, and 2224 UTC 4 June. It is concluded that Allison's surface winds were at their maximum of 33 m s^{-1} for 12 h starting at 1200 UTC 4 June. This was the only time that aerial reconnaissance data showed any kind of eye structure (a partial wall cloud).

In Cuba, Allison produced winds of 21–23 m s^{-1} in Pinar del Rio. Stronger gusts, 28 m s^{-1}, were reported at the weather service office in Havana. Rainfall totals to as high as 457 mm were observed.

The highest reported wind speed observation in Florida was a gust to 26 m s^{-1} at Cedar Key. A 1-min sustained wind speed of 19 m s^{-1} with a gust to 24 m s^{-1} was observed at Turkey Point. A 30-min sustained wind speed of 18 m s^{-1} with a gust to 25 m s^{-1} was measured at the St. George Island Causeway. A 1-min sustained wind speed of 18 m s^{-1} with a gust to 20 m s^{-1} was observed at Apalachicola.

The outer rainbands of Allison spawned a number of tornadoes, waterspouts, and funnel clouds. A waterspout was sighted, at 2005 UTC 4 June, 9 km east of Ponte Vedra Beach, Florida, moving north. A probable tornado struck in eastern Polk County, Florida, from 0245 to 0315 UTC 5 June; a funnel cloud was spotted by two observers but no tornado was seen. However, 75 homes and mobile homes near Haines City apparently received some damage, and trees were down and storage sheds were damaged near West Lake Wales.

There were several tornadoes reported in the northeast Florida–southeast Georgia area on 5 June. A tornado at Jacksonville Beach in Duval County, Florida, around 0738 UTC, downed power lines and trees, flipped over two vehicles, and caused minor damage to fences and houses. A northward-moving tornado was sighted over extreme northern Nassau County, Florida, at 0810 UTC. This twister moved over Saint Marys in Camden County, Georgia, around 0420 UTC. Damage in Nassau County was light, but heavier damage was incurred in

Camden County, where an elementary school in Saint Marys sustained building damage and facilities at the Kings Bay Naval Submarine Base were damaged. Numerous trees were downed at the base as well. At 0930 UTC, a waterspout moved onshore near Brunswick in Glynn County, Georgia, causing minor damage to structures.

A funnel cloud with a possible brief touchdown took place at 1000 UTC near Everret City, also in Glynn County, Georgia. Two tornado touchdowns occurred south of Brunswick, Georgia, at 1045 UTC. A tornado was reportedly sighted near Gainesville, Alachua County, Florida, at 1251 UTC. There was also a possible tornado east of Interlachen in Putnam County, Florida, around 1340 UTC.

Rainfall totals were generally between 100 and 150 mm near the path of Allison, from Florida through North Carolina.

Storm surge heights of at least 2.1 m above National Geodetic Vertical Datum were measured in Apalachee Bay (Turkey Point). Maximum storm surge heights were estimated at 1.8–2.4 m from Wakulla through Dixie counties, 1.2–1.8 m in Franklin County, and 0.6–1.5 m from Levy through Hillsborough Counties.

3) Casualty and damage statistics

The main impact on Cuba was heavy rains, and three deaths were caused by the collapse of structures in western Cuba. Overall, economic losses were apparently not large.

In the United States, there were no direct deaths due to Allison. Damage was greatest in the coastal sections of Dixie, Levy, Taylor, and Wakulla Counties, mainly from storm surge effects, with 60 houses and businesses damaged. A house collapsed at Bald Point in Franklin County. About 5000 people evacuated from the coast. Other coastal effects included mostly minor beach erosion, damage to seawalls and coastal roadways, and the sinking of several small boats. Otherwise, minor wind damage to roofs, signs, power lines, and trees occurred over most of the north Florida peninsula. Some relatively minor crop damage was also reported.

Total damage in Florida is estimated at $860,000, and the tornado near St. Marys, Georgia, caused about $800,000 in damage, bringing Allison's overall U.S. damage figure to $1.7 million.

b. Tropical Storm Barry, 6–10 July

Barry produced gale-force winds over the Canadian Maritime Provinces.

1) Synoptic history

A weak 1019-mb frontal low was located midway between Bermuda and the South Carolina coast at 0600 UTC 5 July. Maximum sustained winds around the low were 5–10 m s^{-1} based on available ship reports. Satellite imagery indicated that the clouds associated with the low gradually became isolated from the frontal cloud band over the next 24–36 h. The satellite imagery also revealed that a low-level cloud system center became better defined just to the west of a small cluster of deep convection, and it is estimated that the frontal low transformed into a tropical depression at 1800 UTC 6 July. Little overall movement was noted on 5 and 6 July.

The center of circulation became better defined by a curved low- to midlevel cloud band and the depression strengthened into Tropical Storm Barry at 0600 UTC 7 July. During this day, the storm began moving toward the north-northeast near 5 m s^{-1} and deep convection moved cyclonically around the western semicircle of the circulation. The deepest convection moved from just north through west to south of the circulation center. The presence of a negatively tilted mid- to upper-level trough just to the southwest of Barry appears to have favored this increase in convection.

The maximum sustained winds of 31 m s^{-1} are estimated to have occurred near 2100 UTC 7 July, after which the central convection decreased dramatically.

Satellite imagery revealed a cloud-free center within relatively weak surrounding convection by 0000 UTC 8 July. The next aircraft reconnaissance report indicated that the minimum central pressure had changed little, but the maximum flight-level winds had decreased about 20 m s^{-1} from those that were measured the previous day. By 1800 UTC 8 July, a small area of deep convection had developed near the low-level circulation center. The storm began accelerating toward the north-northeast in advance of a large amplitude trough moving eastward over the eastern United States. The central dense overcast grew until near 1200 UTC 9 July. Some of this increase in convection may have been related to the passage of Barry over a warm water eddy that bulged northward from the Gulf Stream to near 42°N and between 63° and 66°W.

Convection associated with Barry began to weaken as the tropical cyclone continued to accelerate toward the north-northeast over cooler water. The maximum winds began to spread out away from the cyclone center as Barry gradually lost tropical characteristics, although upper-air soundings indicated that the cyclone still exhibited a warm core when it passed near Sable Island. The center of the storm crossed the eastern tip of the peninsula of Nova Scotia around 2130 UTC 9 July and then continued north-northeastward over Cape Breton Island. Barry became extratropical near the western coast of Newfoundland shortly after 0600 UTC 10 July, when the track ends in Fig. 1.

The weakening remnants lost their identity near the southeast coast of Labrador.

2) Meteorological statistics

On 9 July, Hart Island, Nova Scotia, reported 990.8 mb at 2145 UTC and Fourchu Head, Nova Scotia, reported 990.6 mb at 2248 UTC.

The maximum wind reported by aircraft was 44 m s^{-1} at a flight level of 457 m at 2050 UTC 7 July, while the highest satellite wind estimates at that time were 18 m s^{-1}. The storm was assigned a maximum surface wind speed of 31 m s^{-1}, based on the minimum surface pressure of 998 mb and a pressure–wind relationship given by Dvorak (1984). Similar scatter occurred between the satellite estimates and the aircraft measurements of maximum winds on 8 July as well. Given the large amount of scatter, there is considerable uncertainty in the best track wind speed on Tropical Storm Barry.

c. *Tropical Storm Chantal, 12–20 July*

Chantal was a 31 m s^{-1} tropical storm that developed just east of the Lesser Antilles, recurved around the western periphery of the Atlantic subtropical high pressure ridge, and became extratropical east of Newfoundland as it moved over the far North Atlantic Ocean.

1) SYNOPTIC HISTORY

Chantal originated from a tropical wave that moved off of the coast of Africa on 5 July and soon showed signs of a low-level cloud circulation. By 12 July, satellite imagery showed enough organization for the system to be upgraded to a tropical depression while it was located a few hundred km east of the Lesser Antilles. An aircraft investigated on 13 July and confirmed the existence of a depression.

Even though there were signs of unfavorably strong upper-level westerlies, the depression strengthened to a storm on 14 July, while centered a little under 400 km north-northeast of Puerto Rico. On 15 July, it threatened the southeast and central Bahamas as it was moving west-northwestward, but it gradually recurved toward the north on the 16 and 17 July and did not directly affect the Bahamas.

The storm's maximum 1-min surface wind of 31 m s^{-1} is estimated to have been reached on 17 July as it was moving northward between Bermuda and the U.S. mid-Atlantic coast. Although there was a brief threat to Bermuda, the center passed well to the west of there on 18 July. Chantal turned toward the northeast and accelerated across the North Atlantic shipping lanes where it became extratropical on 20 July.

2) METEOROLOGICAL STATISTICS

The storm was monitored by reconnaissance aircraft from 13 to 18 July. There were 40 penetrations into the center of the storm during this period, which averages to one fix every 3 h. The lowest surface pressure reported from an aircraft was 991 mb at 2338 UTC 16 July and the maximum wind speed was 34 m s^{-1} at a flight level of 457 m and a few hours earlier.

d. *Tropical Storm Dean, 28 July–2 August*

1) SYNOPTIC HISTORY

Tropical Storm Dean developed from a broad quasi-stationary midlevel trough extending from the northeastern Gulf of Mexico across Florida. On 27 July, a weak cyclonic circulation was indicated by buoy reports in the eastern Gulf of Mexico accompanied by surface pressure falls of about 2.5 mb in 24 h. At that time, satellite images showed that thunderstorm activity was disorganized but the upper-level outflow was becoming established. On the 28th, animation of high-resolution visible satellite images clearly showed a low-level cyclonic rotation. Based on that information and on surface reports, it is estimated that a tropical depression formed about 550 km southeast of New Orleans at 1800 UTC 28 July.

A reconnaissance plane was dispatched to the area and located a circulation center with a central surface pressure of 1008 mb. The maximum flight-level wind was 16 m s^{-1}. The depression moved slowly for two days toward the west to west-northwest around a well-established midlevel high pressure ridge located over the central United States. Finally, by the afternoon of 30 July, the surface pressure dropped from 1005 to 999 mb and the flight-level (457 m) winds increased from 21 to 26 m s^{-1}. It is estimated that the depression became Tropical Storm Dean at 1800 UTC 30 July about 100 km from the upper Texas coast. The center of Dean crossed the coast near Freeport, Texas, a few hours later.

Dean weakened to tropical depression status shortly after landfall and then became nearly stationary for about 24 h over the northwest portion of the state producing heavy rainfall. It dissipated at 0000 UTC 3 August as it merged with a frontal zone.

2) METEOROLOGICAL STATISTICS

There were no reports of tropical storm–force winds (1-min sustained) from surface land stations. The highest observed wind was a 23 m s^{-1} gust reported at Galveston Scholes Field at 2115 UTC 30 July. The storm surge flooded Highway 82 between Johnsons Bayou and Holly Beach in Cameron Parish, Louisiana. Minor storm surge flooding of highway 87 occurred on 30 July.

There were two tornadoes associated with Dean. The first occurred in Galveston County at High Island around 2330 UTC and the second touched down just southeast of Anahua near 0300 UTC. Rainfall totals reached as high as 426 mm at Monroe City just east of Houston.

3) CASUALTY AND DAMAGE STATISTICS

There were no reports of injuries or deaths associated with Dean. However, rainfall caused approximately $500,000 in damage. Evacuation of 20 families was necessary in Chambers County due to rainfall flooding.

e. Hurricane Erin, 31 July–6 August

1) SYNOPTIC HISTORY

Erin formed from a tropical wave that crossed from the coast of Africa to the tropical eastern Atlantic Ocean on 22 July. A large area of disturbed weather and two distinct low-level circulation centers accompanied the wave. The circulation centers were oriented from northwest to southeast and moved in tandem toward the west-northwest over the next five days.

By 27 July, both circulations were generating deep convection several hundred kilometers to the northeast of the Leeward Islands. On 30 July, satellite intensity estimates put the wind speed at 18 m s^{-1}, indicating that a tropical storm had formed. However, although the cloud pattern was slowly consolidating and surface pressures were falling ahead of the system in the Bahamas, development was retarded by southwesterly vertical wind shear associated with an upper-level low that was moving southwestward at 5–8 m s^{-1} across Florida. Reconnaissance data on 28–30 July indicated that the system did not have a closed circulation at low levels. Instead it was a very vigorous tropical wave with winds speeds near 21 m s^{-1} reported from ships in the northern part of the cloud pattern. Finally, at 0000 UTC 31 July, a reconnaissance mission determined the existence of a closed low-level circulation and tropical storm–force wind speeds and Tropical Storm Erin had formed over the southeastern Bahamas.

The upper-level low near Florida affected Erin's movement and development. Associated steering currents accelerated Erin from 2.6 to 7.7 m s^{-1} and diverted the cyclone around the northeast side of the low. The temporary and fairly subtle change of heading from west-northwest to northwest might have been insignificant if Erin had not been so close to land. Instead, the track of the center was deflected to a course that was over or near much of the Bahama Island chain and then toward a landfall over east-central (rather than southeast) Florida. As this occurred, enough shearing persisted to permit only slow strengthening. Late on 31 July, Erin became a hurricane while centered near Rum Cay in the Bahamas. A ragged-looking eye appeared on satellite pictures on 1 August. Erin made landfall around 0600 UTC 2 August near Vero Beach, Florida, as a category 1 hurricane, with estimated maximum 1-min wind speeds of 39 m s^{-1}.

Erin's track turned back to west-northwest while the cyclone crossed the Florida peninsula during the morning and early afternoon of 2 August. The cyclone weakened to a tropical storm with 26 m s^{-1} winds during that period, but remained well organized. Upon emerging into the eastern Gulf of Mexico, Erin reintensified on a track that gradually swung back to northwestward at about 5 m s^{-1}. The final landfall occurred near Pensacola, Florida, during the late morning of 3 August. An eye had redeveloped but upper-level outflow was not particularly impressive on satellite images. Erin had 44 m s^{-1} winds (category 2) in a small area of its northeastern eyewall when that part of the hurricane came ashore near Fort Walton Beach.

Erin weakened to a tropical storm in southeastern Mississippi overnight on 3 and 4 August. It was a tropical depression when its track shifted to the north on the 5th and the east on the 6th. The depression merged with a frontal system over West Virginia on 6 August.

2) METEOROLOGICAL STATISTICS

Table 2 lists selected surface observations. The highest wind gust reported at the surface was 66 m s^{-1} in association with a tornado at Providenciales in the Turks and Caicos Islands.

Several reports of 10-min-average hurricane force winds were received from the Bahamas, including 35 and 36 m s^{-1} during the passage of the northeast part of the eyewall over Cat Island at 0200 and 0400 UTC, respectively, on 1 August. These wind speeds are about 80% of the 44 m s^{-1} maximum 10-s 850-mb flight-level winds encountered by the reconnaissance aircraft. Several amateur radio reports included gusts to around 46 m s^{-1} in the Bahamas. The ship *Tampa* was in the northeastern eyewall at 1200 UTC 1 August when it reported a 36 m s^{-1} wind speed.

The basis for the 39 m s^{-1} 1-min wind speed estimate along the Florida east coast was an observation of 38 m s^{-1} recorded by a Florida Institute of Technology anemometer, which made one observation per hour at Sebastian Inlet. This wind appears to coincide with the passage of one of Erin's strongest convective cells at that time (0500 UTC), which was located in the northwestern eyewall. The Melbourne NWS Doppler radar measured a slightly higher value of 44 m s^{-1} in the offshore northeast quadrant of the eyewall at an elevation of approximately 2100 m and the maximum 850-mb flight-level aircraft wind speed was also near 44 m s^{-1}.

It is estimated that the maximum sustained wind during the Florida panhandle landfall was 44 m s^{-1}, at 1330 UTC on 3 August near Fort Walton Beach. This took place in a small area within Erin's strongest sector, the northeastern eyewall, as it swept across the shoreline. That estimate is based largely on the NWS Doppler wind data from Mobile, which showed inbound wind speeds exceeding 51 m s^{-1} at the coast at an elevation of 3000 m from 1320 to 1400 UTC. The aircraft peak 850-mb flight-level wind speed leading up to this time was 47 m s^{-1} in the northeastern eyewall near 1200 UTC, but subsequent excursions into that part of the hurricane were precluded by the hurricane's close proximity to land.

Doppler velocities decreased by about 8 m s^{-1} over the following 2 h and 39 m s^{-1} is the estimated maximum surface wind speed when the center of the eye came ashore around 1600 UTC. Hence, the coastal region immediately west of Fort Walton Beach, including

Pensacola, experienced category 1 conditions, though gusts to near 51 m s^{-1} likely occurred. The FAA system of six anemometers at Pensacola Regional Airport registered a maximum 30-s wind speed of about 31 m s^{-1}. The highest wind speed measured at an official reporting station in the Florida panhandle was a 45-m s^{-1} gust at the Pensacola Naval Air Station. Amateur radio operators relayed unofficial observations of gusts near 49 m s^{-1}.

The hurricane's lowest surface pressure of 973 mb was reported from aircraft near 1330 UTC and again near 1600 UTC 3 August. The latter report placed the center of Erin near the coast and in the southern part of the eye as seen on land-based radar.

The Melbourne NWS Office estimated that Erin generated a 0.6–1.2-m storm tide during the Florida east coast landfall. Storm tides ranged up to 0.6 m along the west-central Florida peninsula. According to the Melbourne office, up to about 300 mm of rain fell southwest through northwest of their site. Several small, brief tornadoes occurred over east-central Florida well after Erin made landfall. One tornado caused minor damage in Titusville. Another occurred near Lake Lizzie, killing two horses. A couple of weak tornadoes were also reported over northeast Florida and in the panhandle near Hurlburt Air Force Base.

Storm tides were estimated up to 2.1 m just west of Navarre Beach and up to 1.2 m along Pensacola Beach. Up to about 127 mm of rain was reported from the panhandle.

3) CASUALTY AND DAMAGE STATISTICS

There were no deaths reported in the Bahamas or in Florida. A total of six drowning deaths occurred in the Atlantic and Gulf of Mexico waters off Florida. The 234-ft gambling and cruise ship *Club Royale* sank in the Atlantic 170 km east of Cape Canaveral and three crew members are presumed dead. A 15-yr-old surfer drowned in a rip current off Palm Beach County. A man and daughter in an inflatable boat were swept from the Cape San Blas area into the Gulf of Mexico where they presumably drowned.

All Bahamas islands from Mayaguana to Grand Bahama suffered damage characterized by the Bahamas Department of Meteorology as mostly minor. Some structural damage, sunken boats, crop loss, and flooding was reported. Losses known to date for Abaco, Grand Bahama, Mayaguana, and Exuma total $400,000.

The American Insurance Services Group estimated $375 million as the loss to insured property in the United States caused by Erin ($350 million in Florida, $20 million in Alabama, and $5 million in Mississippi). Because the total loss is usually estimated by the NHC to be up to about double the insured loss, the total United States loss is estimated at $700 million.

Wind damage occurred over east-central and northeast Florida. Thousands of homes and businesses suffered damage in Brevard County. Less significant damage occurred in other counties in the region. Freshwater flooding from rainfall occurred in the Melbourne and Palm Bay areas and westward in some spots to the Florida gulf coast. Beach erosion occurred along the central Florida east coast, with damage mainly to boardwalks, beach access ways, and the dune system. Light to moderate beach erosion was also reported northward to the Georgia border. Minor erosion occurred along the west-central Florida coast.

The most significant structural damage for the final landfall occurred on Pensacola Beach, Navarre Beach, around Mary Esther, and in northeast Pensacola. More than 2000 homes were damaged there and crop losses were reported. Some beach erosion was reported west of Navarre Beach. Farther inland, about 100 homes were damaged in Alabama. Widespread tree, power line, and crop damage extended inland.

f. Hurricane Felix, 8–22 August

1) SYNOPTIC HISTORY

A tropical wave moved off the African coast on 6 August. Satellite imagery indicated that it quickly displayed evidence of a closed circulation as it moved toward the west. The disturbance became Tropical Depression Seven about 750 km west-southwest of the Cape Verde Islands at 0000 UTC 8 August when loosely organized deep convection increased.

The depression strengthened into Tropical Storm Felix later on 8 August and followed a west-northwestward track at 8–10 m s^{-1} for the next three days. Based on satellite intensity estimates, Felix reached hurricane strength at 0000 UTC 11 August while centered about 900 km east-northeast of the Leeward Islands. Reports from reconnaissance aircraft indicated rapid strengthening from the time of the first eye penetration near 1200 UTC 11 August through 12 August. Maximum sustained surface winds of 62 m s^{-1} are estimated to have occurred near 1800 UTC 12 August. A well-defined eye was visible in satellite imagery at this time, as shown in Fig. 2.

Felix moved northwestward on 12 August, and then turned more toward the north and started to weaken on 13 August. Two factors likely contributed to the weakening: 1) Felix went through a concentric eyewall cycle, and 2) wind shear increased over the system. Aircraft data indicated a large wind field with several wind maxima and no tight center on 13 August, when Felix was centered 150–200 km south-southeast of Bermuda. These characteristics would persist for much of the remainder of the track.

Felix's northward turn was due to a large deep-layer trough over the western Atlantic. The trough split as Felix approached, with one part moving northeastward and filling and the other moving southward to the southwest of the hurricane. The resulting steering pattern al-

TABLE 2. Hurricane Erin selected surface observations, July–August 1995.

Location	Press. (mb)	Date/time (UTC)	Sustained wind ($m\ s^{-1}$)[a]	Peak gust ($m\ s^{-1}$)	Date/time (UTC)[b]	Storm tide (m)[c]	Total rain (mm)
Bahamas							
Cat Island	989.2	1/0600	36		1/0400		
Grand Bahama	987.8	1/2250	35	46	1/2146		
Church Grove, Crooked I.							309
San Salvador	1000.0	1/0100	27		1/0100		
Exuma	1003.3	1/0600	23		1/0100		
Long Island	995.9	31/2100	21		31/1800		
Florida							
Sebastian Inlet	985.1	2/0600	39		2/0500		
Melbourne (MLB)	985.8	2/0700		34	2/0803		224
Vero Beach (VRB)	986.1	2/0554		31	2/0449		62
Orlando Int. (ORL)	994.8	2/0907		28	2/1003		
Daytona Beach (DAB)	1004.7	2/0856		20	2/0816		15
Port St. Lucie City Hall			23	27	2/0600		
Cape Canaveral (USAF)				37	2/0710		
Melbourne NWSO				37[c]	2/0555		258
Melbourne 5°N							211
Vero Beach 4°W							80
Sebastian 2°S							52
Melbourne 10°S	980.8	2/0714					
Ft. Pierce Intercoastal	989.8	2/0415	15	25	2/0415		
Orlando (MCO)							75
MIBFI			12	19	3/0000		65
Jacksonville (JAX)	1010.8	2/1150	11	19	2/1922		53
Mayport Navy Base	1008.0	2/1155		23	2/1255		
Mayport Monty's Marina				26	2/1300		
Fernandina Harbor				27	2/1300		
Jacksonville Bch Pier				31	2/1415		
Gainesville (GNV)	1006.8	2/1445		14	2/1145		46
Ocala unofficial	1002.0	2/1330		21			
Brooksville ASOS				21	2/1113		
New Port Richey ASOS	993.3	2/1437	12	20	2/1755		
St. Petersburg ASOS			16	21	2/1250		
Tampa Int. Arpt. ASOS			15	20	2/1312		
Ruskin NWSO TBW				19	2/1820		
Sunshine Skyway Bridge			14	22	2/1842		
Lake Wales				31	2/1815		
Lakeland (LAL)	993.6	2/1200	10	20	2/1100		
Winter Haven ASOS	987.5	2/1107	16	22	2/0994		
Sarasota (SRQ)	1002.4	2/1347	10	18	2/1952		
St. Augustine							19
Jacksonville Beach						0.5[c]	34
Flagler Beach						1.2[c]	
St. Augustine Beach						0.8[c]	
Marineland						0.8[c]	
Fernandina Beach						1.4[c]	
Near DeFuniak Springs							508
DeFuniak Springs tower							279
Homestead (HST)							98
West Palm Beach (PBI)	1000.9	2/0239	11	14	2/0405		97
Miami (MIA)	1005.2	1/2350					65
Fort Lauderdale	1004.2	2/0048					171
Hollywood							159
West Kendall (TMB)							106
Miami Beach (MIBFI)			12	19	3/0000		
Tallahassee (TLH)	1007.0	2/2130	14	18	2/2117		20
Apalachicola NWS	1001.6	2/2151		26	2/2159		
St. George Island				33			
Panama City Airport			15	33	3/1449		
Panama City Beach (CSBF1)			19	22	2/1300		137
Eglin AFB (VPS)	992	3/1355	22	30	3/1355		71

TABLE 2. *(Continued)*

Location	Press. (mb)	Date/time (UTC)	Sustained wind (m s⁻¹)[a]	Peak gust (m s⁻¹)	Date/time (UTC)[b]	Storm tide (m)[c]	Total rain (mm)
Destin (ASOS)			19	23	3/1151		
Pensacola NAS (NPA)	976	3/1600	28	45	3/1600		56
Whiting Field NAS (NSE)			23	26	3/1625		96
Hurlburt Field (HRT)	988	3/1409	36[c]	44[c]	3/1409		103
Pensacola Regional Airport			31				
Navarre Beach						2.0[c]	
Pensacola Beach						1.1[c]	
Alabama							
Mobile (MOB)(ASOS)	997	3/2029	13	23	3/1950		65
Fairhope (ASOS)			16	22	3/1834		100
NCDC Buoys							
41009	999.9	2/0600	21	27	2/0500		
41010	1007.0	2/0200	18	24	2/0300		
42036	991.9	3/0000	18	23	3/0100		
42007			15	20	3/1930		
C-MAN stations							
SPGF1			18	28	2/0020		
LKWF1	1001.8	2/0300	16	21	1/2200		
SAUF1	1007.9	2/1100	19	22	2/0150		
CDRF1	1001.7	2/1600	21	26	2/1700		
CSBF1			20	28	3/1300		
DPIA1			19	23	3/1800		

[a] NWS standard averaging period is 1 min; ASOS and C-MAN are 2 min; buoys are 8 min; WMO standard is 10 min.
[b] Date/time is for sustained wind when both sustained and gust are given.
[c] Estimated.

lowed Felix to resume a general northwestward motion by 15 August, with this motion persisting into the next day. This track took the storm center within 120 km of Bermuda and toward the North Carolina coast.

The split in the trough resulted in increased ridging over the western Atlantic that appeared to be strong enough to drive Felix into the eastern United States. However, a small weakness remained between 70° and 75°W as indicated by reconnaissance data on 16 August. Felix turned northward into the weakness and almost stalled late on 16 August. It then moved slowly northeastward on 17 August. A second westerly trough failed to pick up the storm on 18–19 August, and Felix performed an anticyclonic loop offshore as the trough bypassed the tropical cyclone. The hurricane accelerated northward on 20 August and northeastward on 21 August in response to a third trough.

During 17–19 August, Felix had an eye diameter of from 90 to 130 km on aircraft radar and rather weak convection in satellite imagery. Despite this, the storm maintained 33–36 m s⁻¹ sustained winds and a central pressure near 970 mb. It is possible that this structure was due to cooler, drier air entering the circulation at low and midlevels. Felix dropped below hurricane strength on 20 August as it moved over colder water and shearing again increased.

Felix became extratropical about 550 km east-northeast of Newfoundland on 22 August. The extratropical cyclone was tracked across the North Atlantic between Scotland and Iceland and then toward Norway.

On a historical note, the threat of Hurricane Felix postponed Bermuda's scheduled vote for independence. Ironically, the first inhabitants at Bermuda were survivors of a hurricane-caused shipwreck on the island in 1609. Their stories helped inspire Shakespeare's writing of *The Tempest.*

2) METEOROLOGICAL STATISTICS

The maximum wind speed of 74 m s⁻¹ from a flight level of 700 mb was measured at 1254 UTC 12 August. The minimum central pressure reported by aircraft was 930 mb at 2328 UTC 12 August, and it is likely that the pressure was somewhat lower during the previous 10 h when there were no aircraft measurements.

During most of 15 and 16 August, the minimum central pressure hovered between 965 and 970 mb, which would normally be consistent with 44–51 m s⁻¹ surface winds. However, maximum flight-level winds reported by reconnaissance aircraft were only 33–39 m s⁻¹ at 850 and 700 mb. This would suggest a minimal hurricane at most. The rawinsonde at Bermuda indicated 28 m s⁻¹ surface winds with 41 m s⁻¹ at an elevation of 120 m. Because a large component of these winds were probably brought to the surface in strong convective bands,

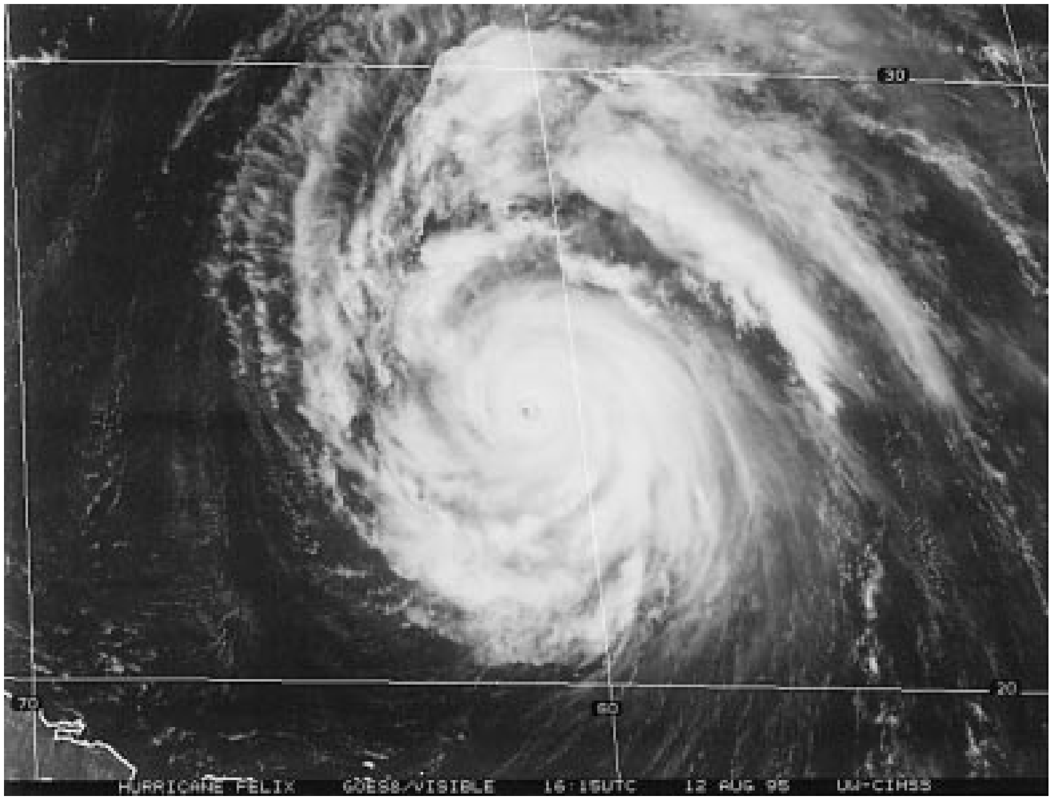

FIG. 2. *GOES-8* visible satellite image of Hurricane Felix at 1615 UTC 12 August 1995. Felix was located about 850 km northeast of Puerto Rico at this time and the maximum 1-min surface wind was estimated at 62 m s^{-1}.

the maximum sustained surface winds are estimated at 36–39 m s^{-1} during this time.

Bermuda reported a minimum pressure of 988.1 mb and maximum 2-min winds of 28 m s^{-1} with gusts to 36 m s^{-1} at 0000 UTC 15 August as the center of Felix passed about 120 km to the south-southwest. No sustained tropical storm force winds were reported by U.S. land stations. Wind gusts to 19 m s^{-1} were reported from the NWS office at Buxton, North Carolina, at 2058 UTC 16 August and at 0102 UTC 17 August while the hurricane was centered about 230 km to the east.

The eye of Felix passed over NOAA buoy 41001 located at 34.7°N, 72.6°W, or about 280 km east of Cape Hatteras, near 1600 UTC 16 August. The buoy reported a 970.4-mb pressure at this time with light winds. A 10-min average wind of 27 m s^{-1} and gusts to 34 m s^{-1} were reported earlier by the buoy near 1200 UTC. Rainbands associated with Hurricane Felix remained offshore of the U.S. coast.

Although the strong winds and heavy rains did not directly affect the United States, large swells generated by Felix produced dangerous surf conditions including some coastal flooding and rip currents from northeastern Florida to New England. Isolated areas of severe beach erosion occurred along the New Jersey coast, but the most significant beach erosion occurred on the Outer Banks of North Carolina. Highway 12 on the Outer Banks was flooded with sand and ocean overwash at times of high tides. Beach nourishment occurred in some coastal areas of North Carolina to the southwest of the Outer Banks.

3) CASUALTY AND DAMAGE STATISTICS

A total of eight deaths were confirmed in association with Felix, three off the North Carolina coast and five off the New Jersey coast. All of these fatalities were a result of drowning. Although there was considerable beach erosion, little significant property damage occurred.

g. Tropical Storm Gabrielle, 9–12 August

1) SYNOPTIC HISTORY

A tropical wave was at the coast of Africa on 27 July and was a well-defined system as it was tracked across the Atlantic and Caribbean over a 12-day period. It moved into the western Gulf of Mexico on 8 August.

A weak low-level cloud circulation was evident from visible satellite imagery on 9 August and aircraft reconnaissance determined that a well-defined low-level wind circulation had formed. The tropical depression stage began on the afternoon of 9 August about 300 km east of La Pesca, Mexico, and 415 km southeast of Brownsville, Texas.

The track from 10 to 12 August was slow and erratically westward with a sharp turn to the south on the 10th and a turn to the northwest on the 11th. With sporadic periods of deep convection, the depression strengthened to a storm on the 10th. The storm gradually intensified to 31 m s^{-1} by late on 11 August, just prior to moving inland. Landfall was on the coast of Mexico just south of La Pesca and about 275 km south of the U.S.–Mexico border. Gabrielle quickly weakened after moving inland.

2) METEOROLOGICAL STATISTICS

Gabrielle came very close to hurricane intensity just before landfall. The 38 m s^{-1} aircraft wind speed measured at a flight level of 457 m is the basis for estimating a maximum 1-min surface wind of 31 m s^{-1} for 1800 UTC 11 August. The corresponding central pressure from an aircraft fix was 990 mb, but a little later, a 989-mb pressure was reported a short distance away from the center, which was too close to the coast for the aircraft to reach. It is estimated that the central pressure was 988 mb at this time.

3) CASUALTY AND DAMAGE STATISTICS

No reports of death have been received and damage is estimated to be minor. It is assumed that 18–31 m s^{-1} winds affected the La Pesca region of Mexico. A newspaper reported up to 610 mm of beneficial rain in the Mexican states of Tamaulipes and Nuevo Leon and flash floods were likely over higher terrain. Storm surge flooding of about 1 m above normal was likely along the Mexican coast to the north of where the center crossed the coast and some beach flooding occurred in southeastern Texas. Eight hundred persons were evacuated in Soto la Marina and San Fernando on the northeast coast of Mexico.

h. Hurricane Humberto, 22 August–1 September

Humberto coexisted with four other tropical cyclones (Iris, Karen, Jerry, and Luis) in the Atlantic basin. The hurricane traveled several days through the open Atlantic without hitting land.

1) SYNOPTIC HISTORY

Hurricane Humberto developed from one of the several strong tropical waves that moved off the coast of Africa in August of 1995. In fact, Dakar, Senegal, reported a 26 m s^{-1} wind speed at 500 mb when the axis of the wave crossed that station on 19 August. Humberto was preceded by a strong tropical wave that eventually became Iris and was followed by another strong wave that triggered Karen.

Satellite images and surface reports indicated that a broad cyclonic rotation was associated with this weather system from the time it moved off the west coast of Africa. However, the convection was disorganized and displaced to the southwest of the circulation center due to the prevailing northeasterly shear. Once the system moved westward over warmer waters and into an area of lighter shear, it developed rapidly. It became a tropical depression at 0000 UTC 22 August and reached tropical storm status 6 h later. Under an upper-level environment very favorable for development, Humberto became a hurricane at 0600 UTC 23 August.

Humberto's motion was influenced by a midlevel trough over the central Atlantic and turned northward on 24 and 25 August and then northeastward over open waters. Humberto maintained hurricane status until 31 August when it weakened to a tropical storm. It was rapidly absorbed by an extratropical low early on 1 September in the central North Atlantic Ocean.

Humberto reached its estimated peak intensity of 49 m s^{-1} and a minimum pressure of 968 mb at 1800 UTC 24 August, based on satellite intensity estimates. Thereafter, the hurricane weakened some, primarily due to interference with the outflow produced by Iris. Once Humberto moved away from Iris, Humberto reintensified and turned northeastward ahead of the extratropical cyclone, which eventually absorbed it.

2) METEOROLOGICAL STATISTICS

The vessel *DBRUK4* was under the influence of Humberto for about 48 h and experienced tropical storm force winds throughout that period. There was a report from that vessel of 31 m s^{-1} winds from the southeast and a pressure of 1005 mb at 1800 UTC 30 August. At that time, the ship was about 35 km north of the center of the hurricane.

i. Hurricane Iris, 22 August–4 September

1) SYNOPTIC HISTORY

Iris formed from the first of four consecutive tropical waves to generate tropical cyclones (Iris, Humberto, Karen, and Luis) on their generally westward trek across the tropical eastern Atlantic Ocean. Iris's evolution was greatly influenced by two of those systems, Humberto and Karen.

The wave associated with the formation of Iris crossed the coast of Africa and began moving over the Atlantic Ocean on 16 August. Surface analyses showed a closed circulation around a 1009-mb pressure center located just south of Dakar. A day later, the circulation was evident in surface observations and satellite pictures near the Cape Verde Islands. Associated deep convection diminished on 18 and 19 August but then gradually redeveloped. From the satellite data it is estimated that the system became a tropical depression at 1200 UTC

22 August, when located about 1100 km to the east of the Lesser Antilles. It became Tropical Storm Iris 6 h later.

The cyclone took a jog to the northwest on 23 August and quickly strengthened. The first reconnaissance flight into Iris took place that evening and found the system to be stronger than operational estimates based on satellite pictures. The aircraft encountered 47 m s^{-1} 10-s winds at a flight level of about 500 m, and a central pressure of 991 mb was reported. From this data, Iris is designated as a hurricane at 1800 UTC 23 August.

Iris moved toward the west-southwest at about 5 m s^{-1} on the 24th and 25th. The change in heading was probably a consequence of a Fujiwhara interaction between Iris and Humberto located about 1400 km to the east.

On 25 August, Iris neared the Lesser Antilles. An upper-level cold low was centered then to the north of Puerto Rico. Westerly vertical wind shear occurred, separating deep convection from the low-level cloud center, disrupting the circulation, and slowing the general westward progress of the cyclone. Iris weakened to tropical storm strength. Reconnaissance aircraft and radar data indicate a reformation of the center to the east of the former position while the system meandered for about a day before moving into the islands.

Steering currents ahead of a trough to the northwest then turned Iris generally toward the north-northwest on 27 August. On this track, Iris moved up the chain of Leeward Islands and strengthened as the shear decreased. Late on the 28th, Iris regained hurricane status over the south-central Atlantic.

Iris began a second Fujiwhara interaction on the 30th, with Tropical Storm Karen to its southeast. The interaction swept the weaker Karen on a spiral path around, and then into, Iris, where it was absorbed on 3 September. The interaction could have contributed to Iris's erratic motion during this period.

An eye appeared intermittently and the intensity of Iris fluctuated from 29 August through 2 September. Iris reached its peak intensity of 49 m s^{-1} several hundred kilometers to the southeast of Bermuda on 1 September. Iris then weakened, temporarily, in an environment of strong vertical wind shear and relatively cool water. It dropped below hurricane strength and became extratropical while accelerating northeastward well to the southeast of Newfoundland on 4 September. It then turned eastward and deepened. The pressure fell from around 1000 mb to near 957 mb in about 48 h. On 7 September, Iris battered western Europe as a powerful extratropical storm with sustained wind speeds near hurricane force.

2) Meteorological statistics

The ship *Pallas Athena* reported 21 m s^{-1} winds at 1200 UTC 1 September while located about 185 km to the south-southeast of the center of Iris.

The only available observation of sustained tropical storm force winds in the Caribbean islands came from Desirade (just east of Guadeloupe) where a 23 m s^{-1} (2-min) wind and 28 m s^{-1} gust occurred. The highest reported gusts elsewhere reached 25 m s^{-1} at Martinique, 21 m s^{-1} at Antigua, 19 m s^{-1} at Dominica, and 18 m s^{-1} at St. Kitts. The lowest pressure reported from the northeastern Caribbean area was 999 mb at Antigua.

The primary meteorological event caused by Iris in the Caribbean islands was heavy rain. The totals were particularly large in Martinique where Ducos (La Manzo) had 450 mm for the event, with 411 mm falling in 24 h. Other peak rainfall rates in Martinique included 48 mm in 30 min, 77 mm in 1 h, and 117 mm in 2 h at Trois Ilets, Vauclin, and Ducos, respectively. An average of 150 mm of rain fell on Antigua.

3) Casualty and damage statistics

Two deaths occurred on Martinique, in homes affected by mud slides. A media summary indicated one death on Guadeloupe.

Few damage reports have been received. There was extensive flooding in low-lying areas and destruction of banana trees on Antigua. Similar damage likely occured on neighboring islands.

j. Tropical Storm Jerry, 22–28 August

Jerry spread heavy rains over portions of the southeastern United States.

1) Synoptic history

Satellite images indicate that an area of cloudiness, associated with a tropical wave that left western Africa on 9 August, moved westward across the tropical Atlantic from 9 to 15 August. Even though convection increased when the wave neared the Lesser Antilles on the 15th, there were no large surface pressure falls noted in those islands. When the wave moved over the eastern and central Caribbean Sea, rawinsonde data from San Juan and Santo Domingo revealed that the system was fairly strong at mid- to lower-tropospheric levels, as evidenced by 15–21 m s^{-1} wind reports east of the wave axis at 850 and 700 mb.

By 19 August, satellite pictures and surface data gave some evidence of a low-level circulation centered just east of Jamaica. No further development occurred during the next couple of days as the system moved west-northwestward to northwestward. On 22 August, cloudiness and convection became better organized near the western Bahamas, and surface reports indicate that a tropical depression formed from this system a short distance southwest of Andros Island at 1800 UTC 22 August. Upper-level winds were partially favorable for development, since anticyclonic outflow prevailed over the eastern half of the depression while outflow was inhibited to the west and northwest.

As the depression moved north-northwestward toward southeast Florida, slow strengthening took place. It is estimated that the system strengthened to Tropical Storm Jerry around 1200 UTC 23 August and the center crossed the east coast of Florida later that same day near Jupiter, with highest sustained winds of 18 m s^{-1}. Jerry moved northwest to west-northwest across the Florida peninsula, weakening back to a tropical depression by 1800 UTC 24 August while nearing the upper west coast of Florida. The forward motion slowed, and after the center drifted a short distance out over the waters of the Gulf of Mexico, Jerry turned toward the north and moved inland again over northern Florida and across the Georgia–Florida border on 25 August.

The weak depression moved slowly northward to north-northwestward over Georgia on the 26th and 27th. Later on the 27th, Jerry turned eastward toward South Carolina. By 0000 UTC 28 August, the circulation of Jerry became elongated in a northeast–southwest-oriented trough, and 6 h later it was impossible to distinguish a circulation center. However, a trough persisted near the Carolinas during the next couple of days and two discrete low pressure centers appeared. The first moved eastward from the coast of North Carolina into the Atlantic without significant development. The second became evident just offshore of the Georgia–South Carolina border early on 29 August. This weak surface low moved southward and southwestward, across the Florida peninsula on 30–31 August, and slowly dissipated over the southeast Gulf of Mexico during the first few days of September. There is some uncertainty over which, if any, of these two lows was derived from the original circulation of Jerry.

2) METEOROLOGICAL STATISTICS

The highest flight-level wind measurement from aerial reconnaissance of Jerry was 23 m s^{-1} at an altitude of 457 m at 1621 UTC 23 August. Sustained winds of 18 m s^{-1} and a gust to 22 m s^{-1} were observed at Lake Worth Inlet, Florida, at 2100 UTC 23 August. Patrick Air Force Base reported sustained winds of 19 m s^{-1} gusting to 26 m s^{-1} at 0640 UTC 24 August. Sustained winds of 19 m s^{-1} with a gust to 28 m s^{-1}, at an elevation of 17 m above ground level, were recorded at Cape Canaveral at 1420 UTC 24 August. The maximum sustained wind of 18 m s^{-1} for Jerry as indicated in Table 1 is based on rounding off the original number to the nearest 5 kt.

A waterspout was observed over Tampa Bay east of the St. Petersburg Pier at 1840 UTC 23 August. A small, brief tornado was observed 19 km west of Zephyrhills in Pasco County, Florida, at 1647 UTC 24 August. No damage was reported. Another, presumably minor, tornado was observed 11 km west of Ruskin in Hillsborough County, Florida, at 1547 UTC 25 August.

Jerry caused very heavy rainfall over Florida, Georgia, South Carolina, and North Carolina. Rainfall totals of up to 250–380 mm were reported over the southwest and west-central coastal sections of Florida from the Naples–Ft. Myers area northward to Tampa, with one total of 427 mm at Golden Gate just east of Naples. Rainfall totals over southeast Florida were generally 75–200 mm, although locally heavier rainfall in the 250-mm range occurred in Martin and St. Lucie counties. Rainfall amounts of at least 200 mm occurred over eastern Georgia. Rainfall totals exceeded 300 mm over portions of western South Carolina. Rainfall amounts reached 225 mm over parts of North Carolina, with local totals up to 432 mm over portions of north-central North Carolina.

Storm tides were generally about 0.5 m or less along the southeast and central east coast of Florida and along the west coast of Florida, due to Jerry.

3) CASUALTY AND DAMAGE STATISTICS

Flooding caused three deaths in South Carolina and three deaths in North Carolina. In Florida, freshwater flooding near the west coast was responsible for most of the damage from Jerry. In Collier County, Florida, 340 buildings were damaged, with 12 uninhabitable. Flooding was particularly severe in Lee and Charlotte counties. Property damage in Florida totaled $1.5 million and damage to agriculture was estimated to be $19 million. Damage figures due to flooding over the remainder of the southeast United States are incomplete. The governor of North Carolina estimated $6 million in uninsured losses in the Raleigh area. This makes a total damage estimate for Jerry of $26.5 million, although additional flood damage likely took place in Georgia and South Carolina.

k. Tropical Storm Karen, 26 August–3 September

Karen was a minimal tropical storm that did not affect land. However, it occurred during a very active period for tropical cyclones and proved to be noteworthy for its interaction with nearby Hurricane Iris.

1) SYNOPTIC HISTORY

Karen originated from a tropical wave that moved off the west coast of Africa to the eastern tropical Atlantic on 23 August. This was a very active day in the Tropics with Hurricane Humberto midway between Africa and the Lesser Antilles, Hurricane Iris about 900 km east of the Lesser Antilles, Tropical Storm Jerry near southeast Florida, and Tropical Storm Gil in the eastern North Pacific. Based on ship and island reports, NHC surface analyses indicated a broad area of low pressure just off the west coast of Africa in association with the tropical wave. The organization of the cloud pattern fluctuated for a few days, and the system became a tropical depression at 1200 UTC 26 August, when satellite imagery showed a well-defined low-level cloud center exposed to the east of a cluster of deep convection. This was about 900 km west of the Cape Verde Islands. At this time, Hurricane Humberto was centered about 1700 km to the west-northwest and Iris, which had weakened to a tropical storm, was centered over the Lesser Antilles about 2800 km to the west of the depression. The depression was moving generally toward the west-northwest at 5–7 m s^{-1} with the low- to midlevel flow.

Deep convection increased and the depression strengthened into Tropical Storm Karen at 0600 UTC 28 August. Hurricane Humberto had moved northward by this time and was centered about 1400 km to the northwest of Karen. Tropical Storm Iris had also moved northward to a position just north of the Leeward Islands, about 2000 km to the west of Karen.

Humberto continued moving northward and then northeastward away from Karen. The steering flow weakened somewhat in the wake of Humberto, and Karen slowed its west-northwestward motion to about 2 m s^{-1} between 28 and 31 August. Karen gradually approached the even slower moving Iris, which had again strengthened to a hurricane by late on 28 August. The upper-level outflow from the stronger Iris resulted in northerly shear over Karen, and the low-level center of Karen was exposed to the north of the accompanying convective activity from 28 to 31 August. During this period, Karen's maximum sustained winds of 23 m s^{-1} were estimated to have occurred. Karen was centered about 1100 km east-southeast of Iris on 31 August, and began moving more toward the northwest, caught in Iris's stronger circulation.

Convective activity associated with Karen became disorganized on 1 September as the tropical storm accelerated and moved cyclonically around the east side of Iris. Karen weakened to a tropical depression on 2 September. However, a tightly wrapped swirl of low- to midlevel clouds could still be seen in satellite imagery moving to the north of Iris late on 2 September. The remnant vortex of Karen was finally absorbed into the stronger circulation of Hurricane Iris on 3 September when located approximately 325 km to the northwest of the center of Iris. This absorption took place over the western North Atlantic Ocean, far from land.

2) Meteorological statistics

Karen was not a threat to land, and therefore, did not require aircraft reconnaissance. However, after flying nearby Hurricane Iris on 2 September, U.S. Air Force Reserve aircraft provided one operational center fix on Karen and measured flight level winds of 21 m s^{-1}.

l. Hurricane Luis, 27 August–11 September

Luis was a category 4 Cape Verde hurricane that wreaked harm and havoc on the northeasternmost of the Leeward Islands, with an estimated 16 deaths and $2.5 billion in damages.

1) Synoptic history

Luis was first detected as a tropical wave and circulation of low clouds on 26 August over the far eastern tropical Atlantic between the coast of Africa and the Cape Verde Islands. The low-level cloud circulation moved westward and is estimated to have developed a weak surface circulation on 27 August near the Cape Verde Islands.

While Luis was developing, there were three other tropical cyclones in the Atlantic, to the west and northwest: Humberto, Iris, and Karen. Luis strengthened from a depression to a storm on the 29th, but its deep convection fluctuated for the next two days while there was strong vertical shear nearby. The shear diminished on the 30th; an eye formed and Luis quickly became a hurricane. The intensification process continued for the next two days as Luis moved west-northwestward. A reconnaissance aircraft reached the hurricane late on 3 September and confirmed the satellite intensity estimates of a category 4 hurricane. Luis was located about 1100 km east of the Lesser Antilles at this time.

The track heading turned from westward to northwestward on 5 September and the hurricane moved across the northeastern Leeward Islands. The center passed directly over Barbuda (Fig. 3) and close enough to the northeast of Antigua, St. Barthelemy, St. Martin, and Anguilla that the southern portion of the eyewall affected these islands. Luis's sustained winds in the eyewall were as high as 59 m s^{-1} at this time, just below 62 m s^{-1} maximum values, which had occurred for the previous 48 h.

Luis was a large hurricane. The inner diameter of the eyewall was 74 km as it moved over the islands. In addition to the eyewall conditions described above, Nevis, St. Kitts, St. Eustatius, and the northernmost British Virgin Islands experienced hurricane-force wind speeds, while tropical storm conditions affected the remainder of the British and U.S. Virgin Islands and the eastern islands of Puerto Rico.

Luis gradually recurved across the North Atlantic and weakened. The center of the hurricane passed about 375 km west of Bermuda on 9 September, causing tropical storm force winds there. Luis became extratropical on the 10th and 11th, as it moved over colder water and it also reintensified. The center moved over eastern Newfoundland on the 11th, but the strongest winds were, by this time, well to the east of the center and remained offshore.

2) Meteorological statistics

The highest reconnaissance wind speed was 75 m s^{-1} at 1306 UTC 4 September at a flight level of 700 mb.

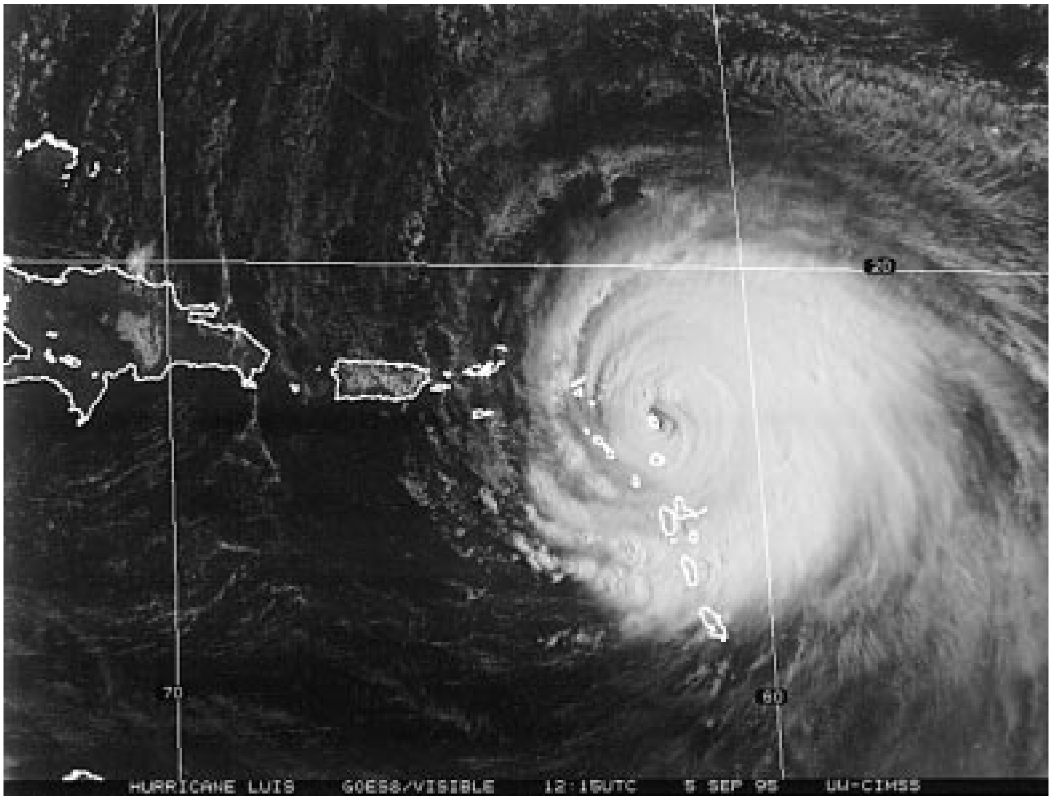

FIG. 3. *GOES-8* visible satellite image of Hurricane Luis at 1215 UTC 5 September 1995, when the eye was directly over the island of Barbuda.

A surface pressure of 945 mb was measured at this time. The surface pressure did not reach its minimum value of 935 mb until late on the 7th, at which time the highest aircraft-measured wind speed had decreased to 62 m s^{-1}. The ship *Teal Arrow* was in the center of the hurricane at 1800 UTC 6 September and measured a sea level pressure of 942 mb. The ship reported sustained winds of 33 m s^{-1} at 1500 UTC and reported 51 m s^{-1} at 2100 UTC and again at 0300 UTC 7 September. The highest ship gusts were 64 m s^{-1} and wave heights to 15 m were estimated.

The official highest sustained 1-min surface wind attained by Luis is estimated to be 62 m s^{-1} from 3 to 5 September while it was approaching the Leeward Islands. This speed is 82% of the highest aircraft wind speed of 75 m s^{-1}. Sustained wind speeds were still as high as 59 m s^{-1} as Luis moved over the islands.

Ten-minute surface wind speeds of 54 and 56 m s^{-1} were observed at Antigua and St. Barthelemy, respectively, and even higher values may have occurred nearby. Since the eye of the hurricane went over Barbuda, it is expected that sustained winds of near 59 m s^{-1} were experienced there. The winds at Anguilla were likely almost as high.

Several days later, on 9 September, Bermuda reported a maximum sustained wind of 21 m s^{-1} as the center passed some 375 km to the west.

The *Queen Elizabeth 2* encountered a wave of 29 m early on 11 September while located 375 km south of eastern Newfoundland and 225 km southeast of the center of the now-extratropical cyclone. At 0130 UTC, the crew reported that the anemometer needle was ''hard over'' at the maximum instrument value of 62 m s^{-1}. Two hours later, they estimated that the maximum sustained winds were 67 m s^{-1}. A nearby Canadian data buoy reported a peak wave height of 30 m at about the same time, but the buoy winds were much less than the ship winds. The best track maximum winds at this time are estimated at 54 m s^{-1}, somewhat less than the ship reports, which were taken near the top of this huge ship's superstructure.

On the afternoon of 8 September, 10 drifting data buoys were deployed by the U.S. Air Force Reserve 53d Weather Reconnaissance Squadron some 550 km ahead of Luis, along 31°N and from 71° to 66°W. One of these buoys measured 8-min winds of 37 m s^{-1} with gusts to 49 m s^{-1} as the hurricane passed, but this observation was not at the location of strongest winds as indicated by aircraft reconnaissance data. The buoys also measured pressure and air and sea temperature and there was a 3.5°C decrease in sea surface temperature to the east of the center after Luis went by, presumably from upwelling.

3) Casualty and damage statistics

The hurricane killed an estimated 16 persons and caused extensive damage when it moved across the northeastern edge of the Leeward Islands of the Caribbean. Nine died in St. Martin, two in Antigua, two in Puerto Rico, one in Guadeloupe, and one in Dominica. Days later, there was one storm-related death in Newfoundland.

Dollar damage totals are unknown. At Barbuda, where a full category 4 hurricane was experienced, the damage to structures was estimated at 70% along with severe flooding and erosion. The estimate for St. Maartin and St. Martin is 60% damage. The prime minister of Antigua was quoted as saying that nearly half the homes on that island were destroyed. A damage estimate for St. Maartin, alone, is $1.8 billion. With great uncertainty, the total damage estimate for Hurricane Luis is placed at $2.5 billion (U.S.).

m. Hurricane Marilyn, 12–22 September

Hurricane Marilyn devastated portions of the U.S. Virgin Islands as a category 2 to near–category 3 hurricane.

1) Synoptic history

Marilyn originated from a tropical wave that crossed from the west coast of Africa to the eastern tropical Atlantic Ocean on 7–8 September. A large circulation of low- and midlevel clouds accompanied the wave, but little deep convection was generated at that time. The system moved westward at about 9 m s^{-1} over the following few days, under upper-level easterlies on the south side of a well-defined anticyclone aloft, which also moved westward.

A low-level circulation was detected on satellite imagery late on 11 September and deep convection developed and became concentrated near the circulation center on the 12th. It became a tropical depression at 1800 UTC 12 September. The cyclone strengthened further, becoming Tropical Storm Marilyn 6 h later. Marilyn reached hurricane strength 24 h after that, at 0000 UTC 14 September, shortly after aircraft reconnaissance first identified a closed eyewall.

Over the following three days, the track gradually became directed toward the west-northwest and then the northwest while the hurricane moved toward a weakness in the subtropical ridge over the central Atlantic Ocean. Marilyn continued to strengthen in an ''embedded center'' cloud pattern, but at a slower rate during that period. It was a category 1 hurricane on 14 September when the center passed about 85 km to the north of Barbados, then just north of Martinique, over Dominica, to just southwest of Guadeloupe.

Marilyn continued moving northwestward over the northeastern Caribbean Sea. It hit the U.S. Virgin Islands during the afternoon and night of 15 September (see Fig. 4) as a strengthening category 2, nearly category 3, hurricane. Hail was reported from the reconnaissance aircraft, an unusual occurrence for tropical cyclones. The eye had a diameter of 37 km. The strongest part of the hurricane, the eyewall to the east and northeast of the center, passed over St. Thomas. Maximum 1-min surface winds at that time were close to 49 m s^{-1}.

After passing just offshore from eastern Puerto Rico early on 16 September, the center of Marilyn was again over the Atlantic Ocean. An upper-level low had developed to the west and this could have enhanced outflow aloft from Marilyn. An eye became distinct on satellite pictures and Marilyn reached its peak intensity, about 949 mb and 51 m s^{-1} (category 3) as it began to turn northward on the 17th. Flight-level data showed some evidence of a concentric pair of eyewall wind maxima. Reconnaissance data indicated a marked weakening later that day. The central pressure rose 20 mb in about 10 h and the peak flight-level winds decreased from 62 to 46 m s^{-1}. The primary (inner) eyewall disintegrated into a few fragments. The weakening was likely caused by some combination of shearing within the system reported by the flight crew, the impact of nearby waters upwelled not long before by Hurricane Luis that were 1°–3°C cooler than normal, and the decaying phase of an eyewall cycle.

Marilyn began accelerating toward the north-northeast late on 18 September and its center passed about 275 km to the west of Bermuda a day later. It had made a brief resurgence, with an eye reappearing in satellite pictures. However, upper-level westerly winds then began to shear Marilyn and the low-level cloud center became partially exposed. Marilyn ceased generating deep convection late on the 21st and became extratropical on the 22d. The remnant circulation meandered over the central tropical Atlantic Ocean for another 10 days before becoming absorbed in a frontal system.

2) Meteorological statistics

Table 3 lists selected surface observations taken during Marilyn's passage over various locations. Over Martinique and Guadeloupe, the maximum wind speed [sustained over the World Meteorological Organization (WMO) standard of 10 min] was 26 m s^{-1} with gusts to 39 m s^{-1}. Guadeloupe had exceptionally heavy rain, with one station, Saint-Claude, recording 508 mm in a 12-h period. The maximum rainfall reported from Martinique was about 225 mm.

Part of Marilyn's eye passed over St. Croix. However, Marilyn's strongest winds were located in the eastern or northeastern eyewall, which passed just offshore.

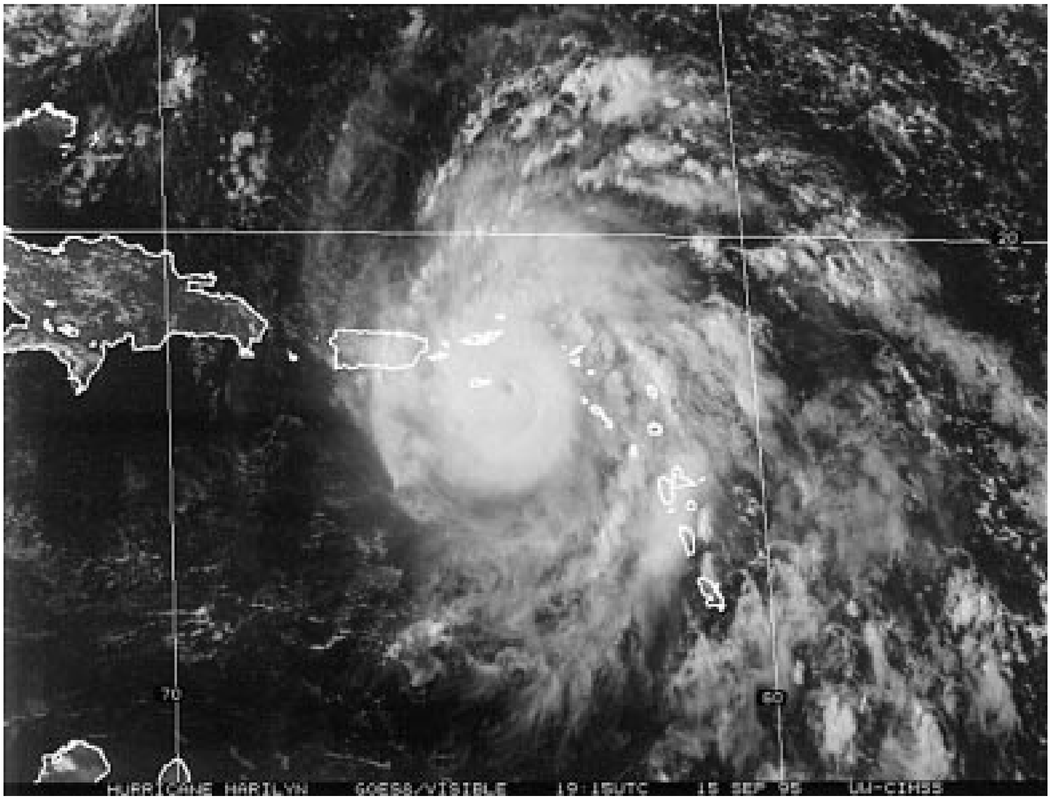

FIG. 4. *GOES-8* visible satellite image of Hurricane Marilyn at 1915 UTC 15 September 1995, when the eye was just east of St. Croix in the U.S. Virgin Islands.

Therefore, the highest 1-min wind speed at St. Croix was likely a little less than the 44 m s^{-1} maximum value assigned to Marilyn in the official best track.

On the other hand, St. Thomas *was* hit by the hurricane's eastern and northeastern eyewall. In addition, the hurricane strengthened as it approached and passed St. Thomas. An uncommissioned FAA Automated Surface Observing System (ASOS) at the St. Thomas King Airport provided the only continuous ''official'' wind record of the event in the U.S. Virgin Islands. Its maximum 2-min wind was 46 m s^{-1} at 0352 and again at 0353 UTC 16 September. (Around then, the peak 10-s wind in the hurricane at the 700-mb flight level was 57 m s^{-1}.) The ASOS measured a gust to 58 m s^{-1} at 0408 UTC. Based on the ASOS data, the estimated maximum 1-min wind speed (for open exposure at 10-m elevation) at that time is 49 m s^{-1}. It is likely that somewhat stronger 1-min winds (perhaps, to category 3) and gusts above 58 m s^{-1} occurred on exposed hills. Some unofficial high wind speed observations remain unconfirmed or have been rejected.

The ASOS measured a minimum pressure of 956.7 mb. This occurred at 0422 UTC when the airport was still experiencing 31 m s^{-1} 1-min winds, apparently on the inside edge of the eyewall. The estimated minimum pressure for Marilyn at that time is 952 mb. This is lower than implied by the data obtained from the Hurricane Hunters. They reported extrapolated and dropsonde pressures of 957 and 960 mb, respectively, at 0305 UTC, and 954 and 958 mb for those techniques at 0600 UTC. This is reminiscent of Hurricane Andrew's landfall over Florida, where the minimum pressure obtained from surface observations was lower than that obtained using aircraft data. The reason for this discrepancy in Marilyn is not obvious.

The storm surge in the U.S. Virgin islands reached 2.1 m, with an isolated storm tide of 3.6 m reported on St. Croix. Rainfall totals reached about 250 mm in St. Croix and St. Thomas.

An unofficial gust to 56 m s^{-1} was reported from the island of Culebra.

The center of Marilyn passed far enough to the east of Puerto Rico that hurricane conditions were apparently not experienced on that island. The naval base at Roosevelt Roads had maximum 1-min winds of 19 m s^{-1} with gusts to 26 m s^{-1}.

Bermuda experienced sustained winds of 20 m s^{-1} with a gust to 27 m s^{-1} during the passage of Marilyn's outer circulation.

3) CASUALTY AND DAMAGE STATISTICS

Marilyn was directly responsible for eight deaths, five in St. Thomas, one in St. John, one in St. Croix, and

TABLE 3. Hurricane Marilyn selected surface observations, September 1995.

Location	Press. (mb)	Date/time (UTC)	Sustained wind (m s^{-1})[a]	Peak gust (m s^{-1})	Date/time (UTC)[b]	Storm surge (m)[c]	Total rain (mm)
Martinique							
Trinite (Caravelle)			26	38	14/1300		
F. St Denis M. (Des Cadets)				31	14/1000		
Ducos (la Manzo)				28	14/1330		
Vauclin (Chateaupaille)				26	14/1400		
Fort de France (Desaix)				26	14/1500		
Macouba (Hab. Bijou)				22	14/1430		
Lamentin (Aeroport)				19	14/1510		
St. Joseph (Riv. Lezarde)				18	14/1230		
Morne Rouge (Champflore)							230
Ajoupa Bouillon (Aileron2)							227
Saint Pierre (Plateau Sable)							163
Gros Morne (Pa lourde)							158
Precheur (Moliere)							155
Riviere Pilote (La Mauny)							153
Ducos (Bois neuf)							152
Guadeloupe							
Marie-Galante			26	38			
Raizet			21	31			
Desirade			20	27			
Moule			16	27			
Saint-Claude							508[d]
Guillard-Basse-Terre							485[d]
Saba							488[d]
Saint-Barthelemy			21	26			
St. Maarten			19	27	15/1600		85
U.S. Virgin Islands							
St. Croix						1.8	
Sailboat *Puffin* at Green Cay				44			296
Annaly							133
Granard							
St. Thomas						2.0	
Noncommissioned ASOS	956.7	16/0422	46	58	16/0352		
Red Hook Bay							253
Puerto Rico							
TJSJ Luis Munoz Int. Airport	1001.1	16/0952	12	20	16/0951		64
TJSJ non-commissioned	1001.3	16/0856	16	21	16/0900		
Culebra (unofficial)	996.5	16/0600		56	16/0600		
Antigua			15	21			
Bermuda			20	27	19/2000		

[a] NWS standard averaging period is 1 min; ASOS and C-MAN are 2 min; buoys are 8 min; WMO standard is 10 min.
[b] Date/time is for sustained wind when both sustained and gust are listed.
[c] Storm surge is water height above normal astronomical tide level.
[d] 12-h total.

one in Culebra (Puerto Rico). Most drowned and were on boats at docks or offshore.

Marilyn caused severe damage to the U.S. Virgin Islands, in particular to St. Thomas. An estimated 80% of the homes and businesses on St. Thomas were destroyed and at least 10 000 people were left homeless. Some of the damage was reportedly attributable to lax construction standards and practices. According to the Federal Emergency Management Administration (FEMA), 30% of the homes on St. John were destroyed and 60% were roofless. About 20%–30% of homes in St. Croix received damage. Trees fell and hotel windows broke there. Hillsides were littered with sheets of metal roofing, wooden planks, and household debris. On Culebra, 250 homes were destroyed or severely damaged and light planes were overturned.

Large waves crashed over the harbor at Dewey, Culebra, flooding streets. Flash floods occurred over northern and eastern Puerto Rico where the La Plata and Manati Rivers overflowed.

The American Insurance Services Group estimated insured losses for the U.S. Virgin Islands and Puerto Rico at $875 million. Because the overall loss is often estimated to be up to about double the insured loss, the total U.S. loss is tentatively estimated at $1.5 billion. The U.S. Virgin Islands Bureau of Economic Research estimated the economic loss at $3 billion. FEMA placed the cost for their programs at $1 billion in the Virgin Islands and $50 million in Puerto Rico. The FEMA totals include losses not traditionally described by the NHC as ''damage,'' such as FEMA's cost to set up field offices, inspector's salaries, disaster unemployment compensation, and crisis counseling.

According to *The New York Times,* the British Virgin Islands were not seriously affected and an unspecified amount of damage occurred in Antigua. According to the Antigua Meteorological Service, that island had extensive flooding in low-lying areas, destruction of banana trees and, otherwise, minimal wind damage.

About 12 000 people went to shelters in Puerto Rico. In the U.S. Virgin Islands, 2243 people were sheltered.

n. Hurricane Noel, 26 September–7 October

Noel was a 33 m s^{-1} hurricane that remained at sea over the eastern Atlantic.

1) SYNOPTIC HISTORY

Satellite pictures and rawinsonde data show that a tropical wave emerged from western Africa on 22 September. Three days later, as the wave neared 30°W, bands of deep convection associated with the system began to acquire some cyclonic shape. By 1800 UTC 26 September, the cloud structure indicated the formation of a tropical depression over the eastern tropical Atlantic.

A mid- to upper-tropospheric trough lay in the path of the developing tropical cyclone. Southwesterly shearing due to the upper-level winds ahead of this trough started to affect the depression as early as 27 September. However, these winds were not strong enough to totally offset the development trend and the depression strengthened into Tropical Storm Noel around 1200 UTC 27 September.

As the cyclone strengthened into a storm, its motion turned from west-northwestward to northwestward, due to the influence of the above trough and an accompanying mid- to upper-level low near 28°N, 44°W. A northwestward movement continued until about 1800 UTC 28 September, when Noel began to take a more northerly heading. Even though upper-level outflow was being impeded to the northwest, satellite intensity estimates indicate that Noel strengthened to a hurricane near 1800 UTC 28 September. Development was halted after that juncture by increasing upper-level southwesterly flow. Moving northward to northeastward, Noel maintained minimal hurricane strength until 30 September, when the center became exposed to the southwest of the cluster of convection associated with the cyclone. Gradual weakening took place, and the forward speed slowed to a crawl on 30 September and 1 October. On 2 October, with its maximum winds reduced to 23 m s^{-1}, Noel moved generally northward at a faster speed. On 3 October, the steering of Noel was influenced by a mid- to upper-level cyclone centered just to the west, and the storm moved north-northwestward for a while.

Shearing diminished as Noel came into the area of lighter upper-level winds near the center of the mid- to upper-level cyclone, and this allowed the storm to restrengthen on 3 and 4 October. By 0000 UTC 5 October, Noel was again a 33 m s^{-1} hurricane. The system maintained this intensity for about 24 h while moving slowly northeastward to eastward. The final weakening commenced at 0000 UTC 6 October, when Noel's winds dropped to just below hurricane strength. A midlatitude trough approached the area, causing Noel to move more rapidly, toward the east-northeast and northeast. Gradually weakening and losing its tropical character as it approached the Azores, the cyclone was absorbed into a cold front at 0000 UTC 8 October.

2) METEOROLOGICAL STATISTICS

In addition to satellite intensity estimates, there were a number of useful ship reports. An observation of 33 m s^{-1} winds from the ship *FNOU* was instrumental in reupgrading Noel to a hurricane at 0000 UTC 5 October.

o. Hurricane Opal, 27 September–5 October

Hurricane Opal made landfall near Pensacola Beach, Florida, as a marginal category 3 hurricane, causing extensive storm surge damage to the immediate coastal areas of the Florida panhandle. It was the first category 3 hurricane to strike the Florida panhandle since Eloise in 1975.

1) SYNOPTIC HISTORY

Satellite imagery and synoptic analyses indicate that Opal originated from a tropical wave that emerged from the west coast of Africa on 11 September. The wave moved westward across the Atlantic into the western Caribbean Sea by 23 September and merged with a broad area of low pressure. The combined system drifted west-northwestward toward the Yucatan peninsula over the following few days without significant development. Deep convection increased near the center of the low and a tropical depression formed about 130 km south-southeast of Cozumel, Mexico, at 1800 UTC 27 September.

Steering currents were week and the tropical depression moved slowly over the Yucatan peninsula for the following three days. Convective banding increased and ship reports suggest that the depression became Tropical Storm Opal at 1200 UTC 30 September while centered near the north-central coast of the Yucatan peninsula. The storm gradually strengthened and moved slowly westward into the Bay of Campeche.

Reconnaissance aircraft investigating Opal over the

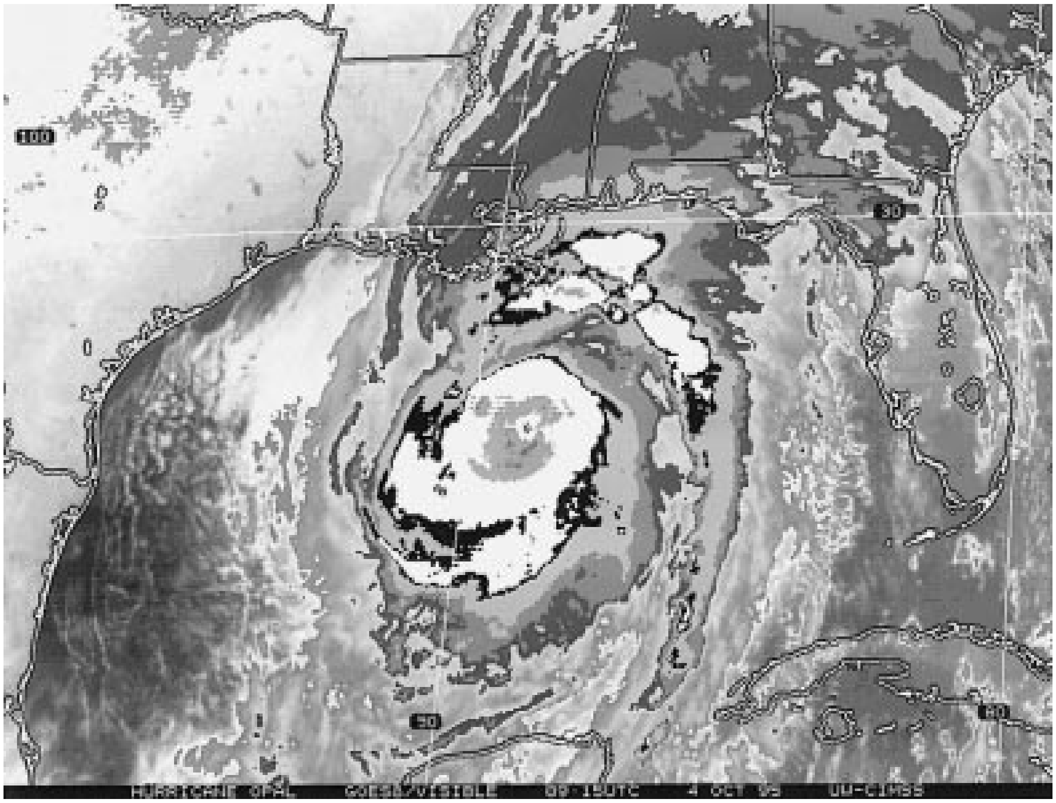

FIG. 5. *GOES-8* enhanced infrared satellite image picture of Hurricane Opal at 0915 UTC 4 October 1995, heading for the northern Gulf of Mexico coast.

southwestern Gulf of Mexico reported that the minimum central pressure steadily dropped. Aircraft reports and satellite estimates suggest that Opal strengthened into a hurricane near 1200 UTC 2 October while centered about 275 km west of Merida, Mexico. A banding-type eye appeared in satellite imagery later in the day while a large amplitude mid- to upper-level trough moving into the central United States began turning Opal slowly toward the north.

On 3 and 4 October, the hurricane turned toward the north-northeast to northeast and gradually accelerated. During this period, the water temperature beneath the hurricane's circulation was near 28°–29°C, and a large upper-level anticyclone was well established over the Gulf of Mexico. Rapid intensification occurred not only as a result of these favorable environmental conditions on the large scale, but also due to significant changes on a smaller scale within the hurricane's inner core. Opal intensified into a category four hurricane early on 4 October at which time reconnaissance aircraft reported a small, 18-km-diameter eye. The minimum central pressure of 916 mb, with maximum sustained surface winds estimated at 67 m s^{-1}, occurred when the hurricane was centered about 465 km south-southwest of Pensacola, Florida, near 1000 UTC 4 October (see Fig. 5). The peak intensity appears to have occurred near the end of an eyewall contraction cycle. Soon thereafter, the small inner eyewall diminished as an outer eyewall became more dominant. The hurricane weakened during this process, but was still a marginal category 3 hurricane as the center made landfall at Pensacola Beach, Florida, near 2200 UTC 4 October.

The hurricane was moving north-northeastward near 10 m s^{-1} at landfall with the sustained hurricane force winds in the eastern half of the circulation primarily between Pensacola Beach and Cape San Blas. The minimum central pressure at landfall was 942 mb. Maximum sustained surface winds are estimated at 51 m s^{-1} in a narrow swath at the coast near the eastern tip of Choctawhatchee Bay about midway between Destin and Panama City. Although no official reports of surface winds were received within this area, data from reconnaissance aircraft and Doppler radar suggest that the peak winds occurred in this location. It should be emphasized that the strongest winds were in a very limited area and most of the coastal areas of the Florida panhandle experienced winds of a category 1 or category 2 hurricane (between 33 and 49 m s^{-1}). Although the winds were diminishing at the time of landfall, extensive damage due to storm surge and breaking waves occurred over much of the coast of the Florida panhandle.

Opal weakened rapidly after moving inland, becoming a tropical storm over southern Alabama and a tropical depression over southeastern Tennessee. The cyclone became extratropical as it moved northeastward over the Ohio Valley and eastern Great Lakes into southwestern Quebec. The strongest winds were far from the center of the cyclone during the extratropical stage.

2) METEOROLOGICAL STATISTICS

The minimum central pressure reported by aircraft was 916 mb at 0945 UTC 4 October. This represented a 53-mb drop in pressure within 24 h and a 42-mb fall within about 12 h. This was a very rapid rate of deepening, but it is not unprecedented. Several western North Pacific typhoons have deepened at an even faster rate. The maximum winds of 75 m s^{-1} from a flight level of 700 mb were measured shortly after the 916-mb pressure report. At 2006 UTC, approximately 2 h prior to landfall, the aircraft reported 65 m s^{-1} at a location 110 km east of the center. At 2203 UTC, near the time of landfall, the aircraft reported 59 m s^{-1}, 100 km east of the center.

A ship with call sign *XCKX* reported 39 m s^{-1} winds at 1200 UTC 4 October while located above 165 km west-southwest of the hurricane center.

The strongest winds reported by a land station were 38 m s^{-1} with gusts to 64 m s^{-1} from Hurlbert Field, Florida. Table 4 lists selected surface observations along the path of Opal.

Isolated tornadoes were reported from the Florida panhandle to the mid-Atlantic states. One fatality occurred in Crestview, Florida, as a result of a tornado. Another tornado injured several people and severely damaged a number of structures as it swept through Charles, Prince Georges, and Anne Arundel Counties in Maryland.

Survey results show storm surge flooding from southeastern Mobile Bay and Gulf Shores, Alabama, eastward through the Florida panhandle to Cedar Key, Florida. Still water mark elevations inside of buildings or tide gauge maximums, which damp out breaking wave effects and are indicative of the storm surge, ranged from 1.5 to 3.0 m above mean sea level. Outside water marks on buildings or debris lines on sand dunes close to the Gulf of Mexico shoreline are more representative of the combined effects of storm surge and breaking waves and these ranged from 3.0 to 7.6 m. For example, the tide gauge at the Panama City Beach pier recorded a maximum of approximately 2.5 m above mean sea level, indicative of storm surge. At the end of the pier a debris line elevation of approximately 5.5 m above mean sea level was recorded. This indicates that breaking waves on top of the storm surge added approximately 3 m. Many structures in this combined storm surge and breaking wave zone suffered major damage.

The combination of Opal and a frontal system resulted in heavy rains along the path of the hurricane. Rainfall totals generally ranged from 125 to 255 mm over portions of the Florida panhandle, Alabama, and Georgia. Rains in South Carolina averaged 50–100 mm while in North Carolina 75–125 mm were common. Highlands, North Carolina, recorded 227 mm and Robinson Creek, North Carolina, recorded 251 mm. Elsewhere, up to 75 mm of rain occurred over portions of the northeast United States from Maryland northward. These rains have been described as beneficial to areas of the northeast United States that had been experiencing a prolonged dry period.

3) CASUALTY AND DAMAGE STATISTICS

The total number of deaths directly associated with Opal is estimated at 59, and were distributed as follows: Guatemala, 31 (from flooding during the developing stages of Opal); Mexico, 19 (from flooding); United States, 9 including Florida (1 from a tornado), Alabama (2 from a tree falling on a mobile home), Georgia (5 from falling trees), and North Carolina (1 from a tree falling on a mobile home).

There were no reported deaths due to storm surge flooding, which is remarkable in view of the vulnerable population and extensive saltwater damage observed.

The Property Claim Services Division of the American Insurance Services Group estimate of insured property damage for the United States is $2.1 billion. Considerable uncertainty exists concerning the amount of additional damage due to flood claims, uninsured property damage (including damage to roads and bridges and other government property), and the cost of cleanup. Based on this, the total damage estimate from Hurricane Opal is $3 billion.

Most of the severe structural damage occurred at the coastline. The crumbled piers, demolished homes, and eroded or submerged highways were primarily a result of the storm surge. In addition, however, strong winds spread damage well inland. Opal downed numerous trees, knocking out power to nearly two million people in Florida, Alabama, Georgia, and the Carolinas. The Robert Trent Golf Course in Opelika, Alabama, lost over 7000 trees during the storm. Many people in Florida were without water for several days.

p. Tropical Storm Pablo, 4–8 October

Pablo was a Cape Verde–type tropical storm that did not affect land.

1) SYNOPTIC HISTORY

Pablo originated from a tropical wave that moved from Africa to the Atlantic Ocean on 3 October. The wave acquired a low-level circulation and became a tropical depression at 1800 UTC 4 October, while it moved westward at 8–10 m s^{-1} and was centered about 1100 km southwest of the Cape Verde Islands.

Pablo became a tropical storm on 5 October. Its movement was rather fast toward the west-northwest and then west across the tropical Atlantic for the next three days

TABLE 4. Hurricane Opal selected surface observations, October 1995.

Location	Press. (mb)	Date/time (UTC)	Sustained wind (m s^{-1})[a]	Peak gust (m s^{-1})	Date/time (UTC)[b]	Storm surge (m)[c]	Total rain (mm)
Louisiana	990.1	4/1953	12	15	4/2150		9
New Orleans (NEW)	991.2	4/1951	15	21	4/2352		30
Mid L. Ponchartrain cswy.			16	20	4/2300		
Mississippi							
Gulfport	985.4	4/1947	15	20	4/2147		
Keesler AFB (BIX)	984.5	4/2125	15[d]	28[d]	4/1956		
Meridian (MEI)	991.6	5/0303	12	18	4/2335		93
Alabama							
Evergreen	980.0	4/2119	15	22	4/2115		206
Mobile (MOB)	978.5	4/2250	17	26	4/2339		190
Downtown Mobile			23	29	4/2100		
Ft. Rucker (OZR)	978.4	5/0059	33[d]	44[d]	5/0024		
Maxwell AFB (MXF)	974.1	5/0355	21	40	5/0327		
Montgomery (MGM)	969.4	5/0256	21	28	5/0245		82
Auburn (AUB)	980.0	5/0400	12	23	5/0300		
Birmingham (BHM)	976.7	5/0655	14	22	5/0453		96
Anniston (ANB)	989.0	5/0631	13	18	5/0335		155
Huntsville (HSV)	982.4	5/0856	19	25	5/0627		62
Florida							
Pensacola (I-10 and E. Bay)	948.2	4/2302	22	32	4/2247		
Pensacola Airport (FFA)			28	32	4/2041		
Pensacola (PNS)				36	4/1930		185
Pensacola (NPA)	955.0	4/2225	27	34	4/2043		176
Ellyson							392
Hurlburt Field (HRT)	960.3	4/2225	38	64	4/2155		169
Fort Walton Beach	960.3	4/2229					
Eglin AFB (VPS)	966.5[d]	4/2156	36[d]	51[d]	4/2304		174
Eglin AFB mesonet:							
B-71 (30.52°N, 86.64°W)			28	46	4/2130		
C-52N (30.58°N, 86.32°W)			28	45	4/2315		
C-72 (30.66°N, 86.34°W)			28	44	4/2315		
Panama City (PAM)	977.7	4/2206	28	38	4/2252		
Apalachicola (AQQ)	991.2	4/2120	14	26	4/2206	1.8	65
St. George Island cswy.				32	4/2149		
Tallahassee (TLH)	993.9	4/2225	14	23	5/0250		32
Tallahassee FSU	995.0	4/2216		28	4/2226		
Turkey Point (TUPF)			19	31	4/2047		
Brooksville (BKV)	1001.6	4/2106	10	14	4/2115		
New Port Richey	1003.5	4/2116	12	16	5/0445		
Tampa (TPA)	1002.1	4/2050	11	20	4/1652		40
St. Petersburg (PIE)	1001.6	4/2000	13	20	4/1948		41
Sarasota	1002.3	4/1848	14	19	4/1648	1.2	71
Winter Haven	1003.5	4/2103	15	19	4/2341		
Georgia							
Fort Benning (LSF)	984.5[d]	5/0656	21[d]	26[d]	5/0555		133
Warner Robbins AFB	994.3	5/0656	15	23	5/0555		25
Atlanta (ATL)	987.5	5/0731	14	22	5/0556		167
Dobbins AFB (MGE)	987.0	5/0755	19[d]	31[d]	5/0608		131
Marietta			12	31	5/0734		
Fulton Co. (FY)							158
Peach Tree City (FSC)							195
Buoys							
42001	963.7	4/0600	27	34	4/1000		
42003	992.8	4/1200	22	28	4/0900		
42007	979.5	4/2100	27	35	4/1900		
42036	995.4	4/2100	18	22	4/1800		
C-MAN stations							
Grand Isle (GDIL1)	990.0	4/1900	21	27	4/1400		
Southwest Pass (Burl1)	985.4	4/1700	33	39	4/1700		
Dauphin Is. (DPIA1)	970.0	4/2126	27	34	4/2150		
Keaton Beach (KTNF1)	998.0	4/2000	15	24	4/2100		
Cedar Key (CDRF1)	1000.2	4/2100	16	24	4/2300		

[a] NWS standard averaging period is 1 min; ASOS and C-MAN are 2 min; buoys are 8 min; WMO standard is 10 min.
[b] Date/time is for sustained wind when both sustained and gust are listed.
[c] Storm surge is water height above normal astronomical tide level.
[d] Estimated.

under the influence of deep easterlies. It is estimated that the storm's sustained winds reached their maximum value of 26 m s^{-1} on the 6th and then stayed near 23 m s^{-1} until the 8th, when the storm encountered very strong vertical shear and quickly dissipated while centered about 250 km east-southeast of Barbados.

2) METEOROLOGICAL STATISTICS

A reconnaissance aircraft investigated Pablo on the morning of 8 October and was unable to locate a well-defined low-level wind center. The ship *Bruma* reported 26 m s^{-1} winds on the 6th while located about 110 km north of Pablo's center, and this report is the basis for the storm's maximum wind estimate.

q. Hurricane Roxanne, 7–21 October

After striking the east coast of the Yucatan peninsula as a category 3 hurricane, Roxanne meandered in the Bay of Campeche for several days causing death and destruction along the coast of the Mexican states of Yucatan, Campeche, and Tabasco.

1) SYNOPTIC HISTORY

Roxanne formed from a complex combination of several synoptic-scale features (a broad low-level low pressure area, a tropical wave, and an upper trough) that interacted over the western Caribbean Sea.

On 6 October, radiosonde data from the western Caribbean indicated a broad well-established low- to mid-level cyclonic circulation with cloudiness and showers between the Cayman Islands and Honduras. A distinct tropical wave, tracked from the coast of Africa on 26 September, became convectively active over the central Caribbean on 4 October. The wave reached the western Carribean early on 7 October and interacted with the preexisting area of disturbed weather. A slow westward-moving upper-level trough was at that time located over the Windward Passage, to the east of an upper-level anticyclone centered over the southeastern Gulf of Mexico. This combination resulted in diffluent, and presumably divergent, northerly winds over the low-level disturbance. High-level divergence has long been recognized as a factor in the development of incipient disturbances (e.g., Dunn and Miller 1964).

At the same time, a broad, weak 1004-mb low pressure area was located near the east coast of Nicaragua. Satellite images indicated a gradual increase in organization and cloud-banding features began to develop early on 7 October as the tropical wave reached the area. It is estimated that the system became a tropical depression at 1800 UTC 7 October just east of Nicaragua. The next day, a reconnaissance plane confirmed the presence of a tropical depression with a pressure center of 1004 mb and 15 m s^{-1} winds. Satellite images and surface observations indicated a steady intensification. The depression became Tropical Storm Roxanne at 0000 UTC 9 October and a hurricane by 0600 on the 10th. During that period, data from reconnaissance planes indicated that the pressure dropped to 989 mb and by 1200 UTC on the 10th the pressure was down to 972 mb. Prior to intensification, the low-level center was located on the northern edge of the deep convection due to the northerly winds produced by the upper high over the Gulf of Mexico. However, the upper trough previously located over the Windward Passage became a cutoff low and moved west-southwest into Central America. This allowed the outflow to become established in all quadrants.

Initially, Roxanne was a threat to Cuba and the Cayman Islands as it moved northward in response to a weak trough over Florida and the eastern Gulf of Mexico. The trough moved eastward and was replaced by a high pressure system. Roxanne turned northwestward and then westward toward the Yucatan peninsula and intensified.

During the early afternoon of 10 October, a well-defined eye became apparent on satellite images. By late on the same day, Roxanne reached its maximum sustained wind speed of 51 m s^{-1} and a minimum pressure of 956 mb while located just to the east of Cozumel (see Fig. 6).

Radar imagery from Cancun indicated that the northern eyewall crossed the coast at Cozumel at 2340 UTC 10 October. The hurricane made landfall just north of Tulum, on the mainland, Mexico, just to the southwest of Cozumel about 0200 UTC 11 October. Roxanne continued westward over the Yucatan peninsula and emerged over the Gulf of Campeche as a minimal hurricane, but temporarily weakened to tropical storm status. It then regained hurricane intensity and maintained that status for about 60 h before weakening to a tropical storm and then to a tropical depression.

The steering currents were weak when Roxanne was in the Bay of Campeche. Consequently, the hurricane meandered within an area of less than 450 km for almost a week. During that period, several shortwave troughs and ridges passed by to the north of Roxanne, forcing the tropical cyclone to move a short distance either southeastward or northwestward. Rainbands and waves of 4–6 m pounded the coast from the State of Campeche to Veracruz throughout that time. Eventually, Roxanne was forced to move southward toward Veracruz by an approaching strong cold front and the remnants moved inland on 21 October.

2) METEOROLOGICAL STATISTICS

The minimum pressure and maximum wind speed reported by reconnaissance aircraft was 956 mb and 59 m s^{-1} (700 mb) at 2152 UTC 10 October. An automatic station near Merida reported sustained winds of 33 m s^{-1} with gusts to 56 m s^{-1} at 1900 UTC 11 October, when the center was located over land and about 150

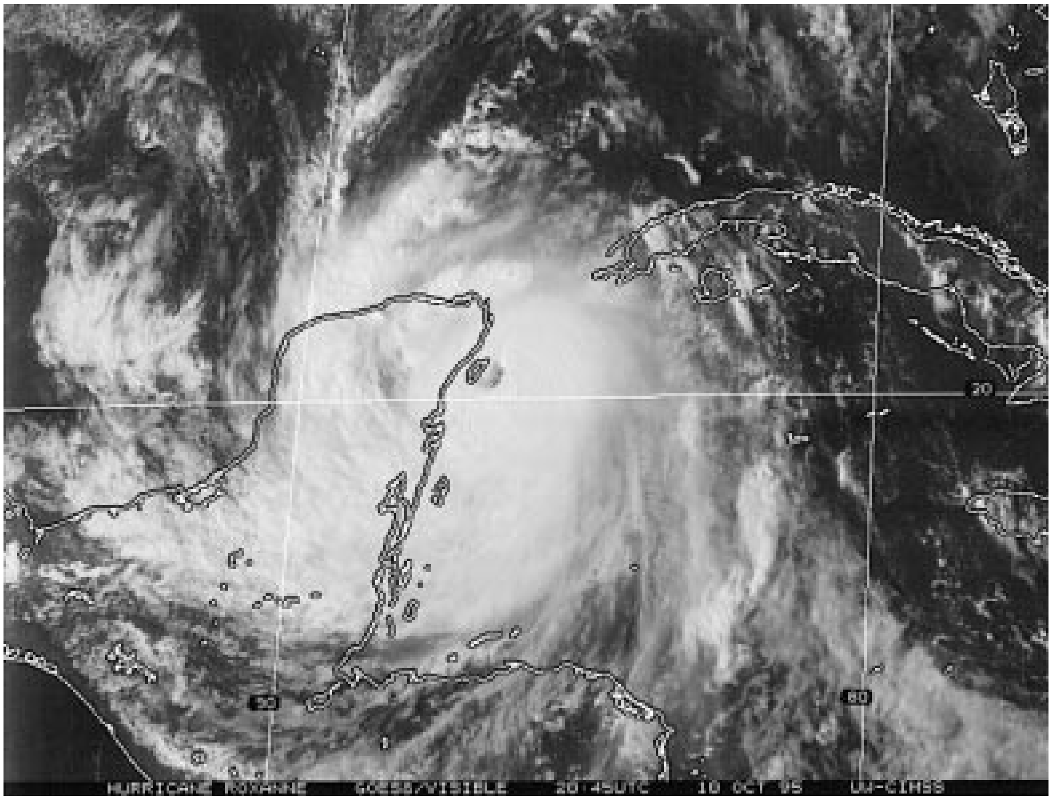

FIG. 6. *GOES-8* visible satellite image of Hurricane Roxanne at 2045 UTC 10 October 1995, as the eye was nearing Cozumel, Mexico.

km to the south of the station. On the 15th, when Roxanne moved over the Bay of Campeche, sustained winds of 33 m s^{-1} with gusts to 36 m s^{-1} were reported from Paraiso. A report of 29 m s^{-1} with gusts to 33 m s^{-1} was received from Champoton and 23 m s^{-1} with gusts to 26 m s^{-1} came from Tuxpan. Villahermosa reported 28 m s^{-1} with gusts to 36 m s^{-1}. On the east coast, southwest of Cozumel (20°30′N, 86°57′W) and about 50 km to the north of where the center made landfall, a surface pressure of 978 mb and winds gusting to over 60 m s^{-1} were reported and a total of 137 mm of rain was measured during a period of about 36 h.

A weather station in Veracruz reported a rainfall total of 305 mm of rain and the Tabasco Observatory reported 241 mm.

3) CASUALTY AND DAMAGE STATISTICS

The death toll is estimated at 14 according to the Ft. Lauderdale *Sun-Sentinel*, 20 October 1995. Five of these deaths were caused by a petroleum work barge that sank with 245 people on board. According to Mexican authorities, more than 40 000 homes were damaged by Roxanne in the states of Campeche, Quintana Roo, Tabasco, Veracruz, and Yucatan. Numerous crops were damaged, cattle drowned, and roads were washed out or blocked by mud and rock slides. The road between the City of Carmen and Campeche was completely destroyed. Thousands of people were evacuated. There are unconfirmed reports that many hotel lobbies in Cancun and Cozumel were damaged from pounding waves. Extensive tree damage was observed in Cozumel. Storm tides and swollen rivers caused the worst flooding in Campeche and Tabasco since 1927. It appears the worst damage was produced by the pounding of high waves along the shore for several days.

This area had previously been affected by Hurricane Opal a week or two before and it is difficult to separate the damage caused by Opal and Roxanne. The estimate of the combined damage in the Yucatan peninsula is $1.5 billion.

r. Tropical Storm Sebastien, 20–25 October

1) SYNOPTIC HISTORY

Tropical Storm Sebastien originated from a tropical wave that moved westward across the Atlantic Ocean from 13 through 19 October. Associated thunderstorms remained unorganized and mostly to the south of 15°N during that period. On the 20th, deep convection became more concentrated about 650 km to the east of Barbados, and based on satellite imagery, it is estimated that the system became a tropical depression at 1200 UTC on the 20th and a tropical storm at 0000 UTC on the 21st.

From 20 to 22 October, Sebastien was embedded within the outer part of the circulation associated with a large, deep low pressure system centered just northeast of Puerto Rico. The associated steering currents moved Sebastien toward the northwest and then north at about 8 m s^{-1} during that period. Southwesterly vertical wind shear precluded significant development and, based on a ship observation, Sebastien reached its peak intensity of 28 m s^{-1} at 1800 UTC 22 October. At that time, its exposed low-level cloud center was located about 650 km to the northeast of the northern Leeward Islands.

Sebastien began moving with the low-level flow toward the southwest on 23 October. This pushed Sebastien directly into the upper-level southwesterly winds, displacing the coldest cloud tops about 185 km to the east and northeast of the center. Sebastien weakened to a tropical depression during the evening of 23 October while it moved under the upper-level cyclonic circulation. Its dissipating circulation of low clouds was near the U.S. Virgin Islands about 24 h later, while some remnant deep convection persisted well to the east.

2) METEOROLOGICAL STATISTICS

The basis for the estimated maximum wind speed of 28 m s^{-1} is a 27 m s^{-1} wind speed observed on the ship with call sign *ELSE5* while it was located 110 km northeast of the center at 1800 UTC 22 October. The maximum flight-level reconnaissance wind at about 500 km was also reported at about this time and was 26 m s^{-1}. The only other reports of tropical storm force or higher wind speeds came from the ship *Sea Wolf.* It had 19 and 20 m s^{-1} winds at 1200 and 1400 UTC, respectively, on 21 October, 65–85 km to the east of the circulation center.

s. Hurricane Tanya, 27 October–1 November

1) SYNOPTIC HISTORY

Tanya originated from a tropical wave that moved off the west coast of Africa in mid-October. This wave followed one that spawned Tropical Storm Sebastien, and was not easily identifiable as a cloud mass on satellite pictures until 20 October, while located in the central tropical Atlantic Ocean. The wave moved slowly westward for a few days. By 24 October, cloudiness associated with the wave merged with an area of convection to the east and northeast of Tropical Depression Sebastien. This weather was partly associated with an upper-level cyclone that was producing shearing winds over Sebastien, causing its demise. At 1800 UTC 25 October, a low cloud swirl was evident in the vicinity of 22°N, 60°W. However, the associated deep convection was not very close to the center. The low-cloud swirl became more pronounced on satellite images on the 26th. By 0000 UTC 27 October, surface observations indicated a definite closed surface circulation and the tropical depression stage of Tanya began then, centered about 900 km northeast of Puerto Rico.

The movement of the tropical cyclone was controlled mainly by two factors: shortwaves in the midlatitude westerlies and the upper-level cyclone in Tanya's vicinity. Initially the cyclone moved northeastward, in response to an approaching shortwave trough. However, due to the effect of the upper cyclone, Tanya turned more eastward and slowed.

Because of the influence of the upper-level cyclone, the development of Tanya was not like that of a typical tropical cyclone in the deep Tropics. On 27 and 28 October, the system had some subtropical characteristics—that is, a large comma-shaped cloud band and strongest winds well removed from the center. Nonetheless, Tanya's winds increased to tropical storm force by 1200 UTC on the 27th and gradual strengthening continued thereafter. Convection developed closer to the center by 1800 UTC on the 28th, and on the following day the cloud pattern was more symmetrical about the center. Tanya reached hurricane strength around 1200 UTC on the 29th, when a small eye was observed in the middle of the central dense overcast.

While Tanya was strengthening into a hurricane, its motion was cyclonic along roughly a half-circular path, again due to the adjacent upper low. This movement continued into 29 October, when a strong eastward-moving midtropospheric trough over the western Atlantic, and associated cold front near Bermuda, began to influence the track of the hurricane. Tanya turned north-northeastward on the 30th, and east-northeastward later that same day. Early on the 31st, while still embedded in a narrow wedge of warmer air between cooler air masses over the western and eastern Atlantic, the system acquired its peak intensity of 39 m s^{-1} winds with a 972-mb central pressure.

On 1 November, Tanya veered to the east and weakened to a tropical storm and headed in the general direction of the Azores. As the storm neared those islands, the movement became more northeasterly, taking the center just to the north of the Azores. Tanya was becoming extratropical as it passed near the Azores. The extratropical cyclone turned north-northeastward, then northward, and was absorbed into a larger low pressure system over the North Atlantic by 0600 UTC 3 November.

2) METEOROLOGICAL STATISTICS

There were some surface observations from the Azores of sustained gale force winds. Lajes Air Base on Terceira measured sustained winds of 18 m s^{-1} at 2255 UTC with gusts to 30 m s^{-1} at 2343 UTC 1 November. Santa Maria Island reported sustained winds of 20 m s^{-1} at 2300 UTC on the 1st, with gusts to 26 m s^{-1} at 0200 UTC on the 2d. The lowest pressure ob-

TABLE 5a. Official track forecast errors (km).

	Forecast period (h)					
	0	12	24	36	48	72
1995 mean	22	87	161	230	297	432
1995 mean CLIPER	22	100	206	319	423	606
(No. of cases)	(446)	(446)	(410)	(375)	(343)	(280)
1985–94 mean	28	93	182		360	549
1995 departure from 1985–94 mean	−20%	−07%	−11%		−17%	−21%
1995 maximum	163	343	660	875	927	1216

TABLE 5b. Official maximum 1-min wind speed forecast errors (m s^{-1}).

	Forecast period (h)					
	0	12	24	36	48	72
1995 mean	−0.8	−0.6	−0.8	−1.1	−1.9	−2.0
1995 mean absolute	1.7	3.2	4.8	6.1	7.8	9.8
1995 mean SHIFOR	−0.8	−0.7	−1.0	−1.5	−1.9	−3.3
1995 mean absolute SHIFOR	1.7	4.0	5.6	6.8	7.9	8.9
(No. of cases)	(446)	(446)	(410)	(375)	(343)	(279)
1985–94 mean	−0.8	−0.8	−1.0		−2.1	−2.5
1985–94 mean absolute	2.4	4.0	5.9		8.5	10.8
1995 departure from 1985–94 mean absolute	−30%	−19%	−18%		−08%	−10%
1995 maximum absolute	15	21	23	26	31	31

served in the Azores was 973.5 mb at Horta on the island of Faial.

Many ships reported tropical storm force winds in association with Tanya. A ship, with call sign *GBSA*, had the misfortune of being near the center of Tanya twice: on 29 October, when Tanya was a hurricane; and on 2 November, when Tanya was an extratropical storm.

4. Verification

The NHC issues an official 72-h track and intensity forecast on all tropical cyclones in the Atlantic basin (and in the eastern Pacific basin) and verifies these forecasts by comparison with the best tracks described in section 1. Table 5a lists the yearly mean track forecast errors for 1995, along with the previous 10-yr means and Table 5b lists similar statistics for intensity forecast errors. The errors in Table 5 are for tropical storm and hurricane stages only, and do not include tropical depression stage.

A track error is defined as the great-circle distance between a forecast position and a best track position of the tropical cyclone center. The mean track errors for 1995 range from 22 km at the 0-h forecast period to 432 km at 72 h. These errors are less than the previous 1985–94 means at all forecast periods. Mean 1995 errors are also listed in Table 5a for the CLIPER (climatology and persistence) statistical track forecast model for the same 446 cases used to determine the official errors. The CLIPER model was designed by Neumann (1972) and is based on linear regression between center motion and several parameters, including initial (0-h forecast period) position, initial motion, past 12-h motion, maximum wind speed, and day number. The best track dataset for the period 1931–70 was used to determine the predictive regression equations. The operational CLIPER forecasts in Table 5a represent a skill level attainable using only the operational estimates of initial position and motion as input. It is customary to estimate the skill of the official forecast as its improvement over the CLIPER forecast. From Table 5a, it can be determined that the mean official track error improvement over CLIPER ranges from 13% at 12 h to near 30% at 36 h and beyond.

There are two intensity forecast errors. One error is the difference between the forecast maximum 1-min wind speed and the best track wind speed. A positive error means that the forecast wind speed is higher than observed and vice versa. The second intensity error is the absolute value of the error without regard to its sign. The sign of the error might be considered as a bias, while the absolute value represents the magnitude of the error. The SHIFOR model (Jarvinen and Neumann 1979) is a statistical model for intensity that is analogous to the CLIPER model and can be used to estimate the skill of the official intensity forecasts. Table 5b shows that the official 1995 mean absolute official intensity errors are nearly as large or larger than the 48- and 72-h SHIFOR errors. It is concluded that there is no ''skill'' in the official intensity forecast after 36 h.

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