Atlantic Hurricane Season of 1980

MILES B. LAWRENCE AND JOSEPH M. PELISSIER
National Hurricane Center, NWS, NOAA, Miami, FL 33146

(Manuscript received 19 April 1981)

ABSTRACT

A summary of the 1980 hurricane season is presented. Eleven named tropical cyclones were tracked, of which nine reached hurricane force. Allen, an intense storm, affected a number of Caribbean countries before making landfall on the Texas coast.

1. Introduction

a. General statistics

A tropical cyclone is named when maximum sustained winds reach gale force (34 kt). Hurricane status is reserved for wind speeds of 64 kt or higher. During 1980, eleven storms in the Atlantic region were named, of which nine attained hurricane status. This compares to the average for the past 30 years of 9.8 named storms and 6.0 hurricanes. It is unusual to have as many as nine hurricanes in a season. The last time that this occurred was in 1969 when 12 hurricanes were counted. Since 1886, there have been only eight seasons with nine or more hurricanes, which is an average frequency of once every 12 years.

Storm tracks and statistics for 1980 are given in Fig. 1 and Table 1, respectively. The first storm of the season, Allen, began on 1 August, more than one month after the median starting date of 26 June. However, storm activity extended late into November, when Hurricanes Jeanne and Karl occurred.

b. Storm origin

Hurricanes Allen, Bonnie, Earl, Frances and Georges originated from westward-propagating tropical waves which moved off the west coast of Africa. Tropical Storm Hermine, whose track starts in the Caribbean, also can be traced to a tropical wave origin.

In contrast, Hurricanes Charley, Ivan and Karl formed north of 35°N and were of extratropical origin. The two remaining storms, Danielle and Jeanne, are not as easily classified. Danielle's development was associated with a mid-tropospheric low pressure system, whereas Jeanne developed in the northwest Caribbean within a cloud mass that had persisted there for several days. In both cases, a weak tropical wave may have interacted with the preexisting weather disturbance during the storm's formation period.

Tropical and extratropical storms may be considered to be on opposite ends of a spectrum. On one end there is the extratropical system, whose primary energy source is derived from synoptic-scale horizontal temperature gradients (i.e., the rising of warm air or the sinking of cold air results in a transformation of available potential energy into the kinetic energy of the cyclone). On the other end of this spectrum is the classical tropical system, where the main energy source is the release of latent heat during the condensation process.

Tropical cyclones are characterized by a warm-core thermal structure, while extratropical cyclones are considered to be cold-core. Of course, there are many systems in the middle of this spectrum where both energy sources are operating simultaneously. Attempts to classify these intermediate systems have resulted in the "subtropical" designation.

When temperature data are available, tropical systems are classified without ambiguity. As an example, Fig. 2 shows an 850 mb radial temperature profile for Hurricane Allen, based on multiple penetrations of the eye of the storm by reconnaissance aircraft on 8 August. It is seen that the temperature within 20 km of the center is ~5°C higher than elsewhere.

When such data are unavailable, indirect methods are used to assess the cyclone's thermal structure. Storms that originate from upper level cold lows, or other cold-core circulations, are presumed to be subtropical. However, if satellite photographs show that cloud features appear tropical in nature (e.g., an eye-type feature, central dense overcast, etc.), then tropical status may be assigned.

This was the case in 1980 for Hurricanes Charley, Ivan and Karl. Even though they were of extratropical origin, they eventually evolved into hurri-

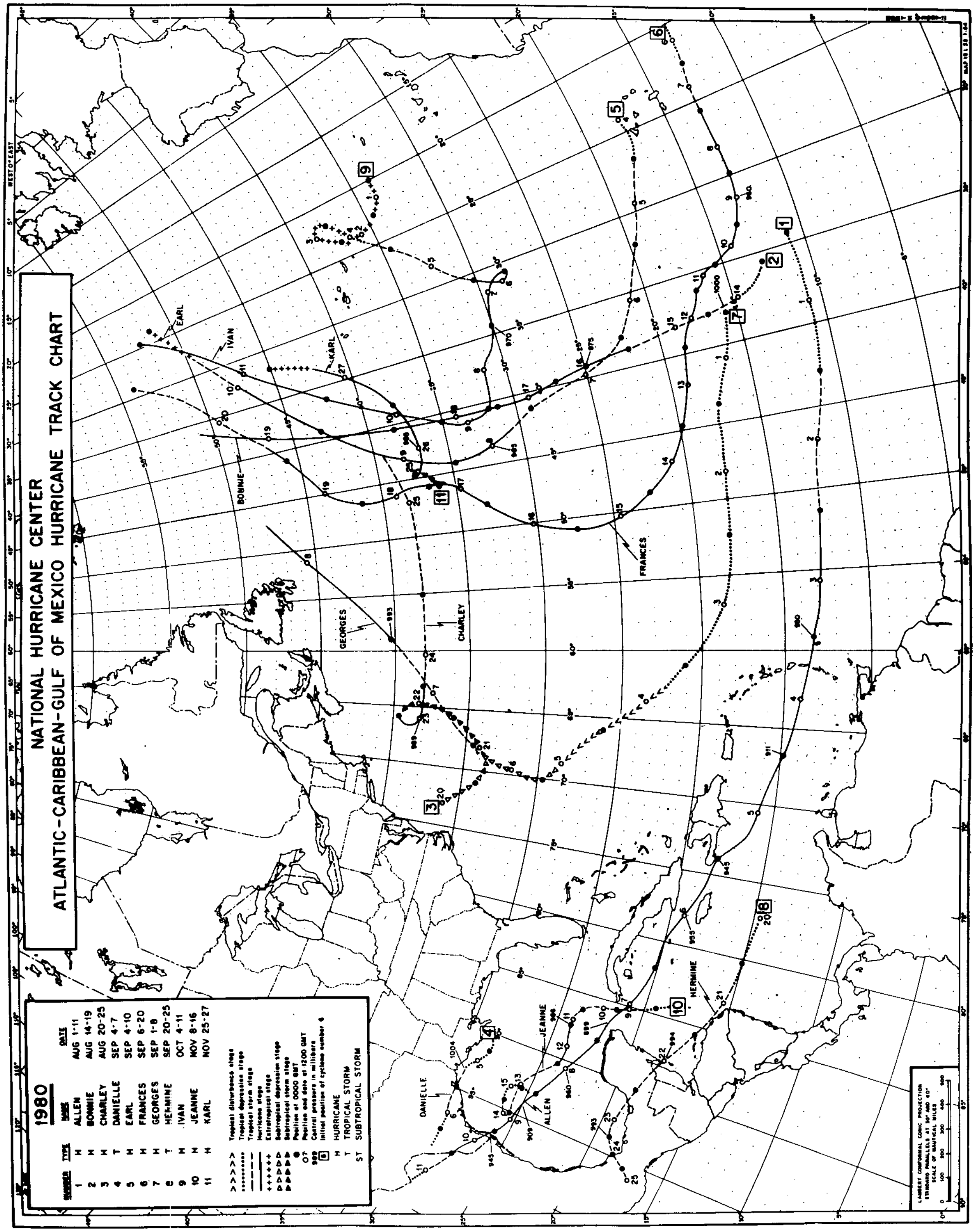


FIG. 1. Tracks of 1980 tropical cyclones.

TABLE 1. Summary of North Atlantic tropical cyclone statistics, 1980.

Cyclone number	Name	Class[1]	Dates[2]	Maximum sustained wind (kt)	Lowest pressure (mb)	U.S. damage (millions of $)	Deaths
1	Allen	*H*	August 1–11	165	899	300	U.S. 2 Caribbean 234
2	Bonnie	*H*	August 14–19	85	975		
3	Charley	*H*	August 20–25	70	989		
4	Danielle	*T*	September 4–7	50	1004	minor	1
5	Earl	*H*	September 4–10	65	985		
6	Frances	*H*	September 6–20	100	960		
7	Georges	*H*	September 1–8	70	993		
8	Hermine	*T*	September 20–25	60	993		
9	Ivan	*H*	October 4–11	90	970		
10	Jeanne	*H*	November 8–16	85	986		
11	Karl	*H*	November 25–27	75	985		

[1] *T* = tropical storm (winds 34–63 kt) and *H* = hurricane (winds 64 kt or higher).
[2] Day starts at 0000 GMT.

canes, based on their appearance in satellite pictures.

c. *Storm tracks*

Storms originating from African waves constitute a subset of interest. The classical Cape Verde hurricanes are of this type, including such recent notables as Allen (1980) and David and Frederic (1979). There were six named storms in this category in 1980.

Allen, in early August, moved steadily west-northwestward for 10 days. Such a track requires a steady steering current and is dependent on the establishment of a strong Atlantic subtropical high-pressure ridge.

The next four storms which formed in the Cape Verde area all recurved to the north. Bonnie moved almost due north; then each succeeding storm tracked a little farther westward before recurving.

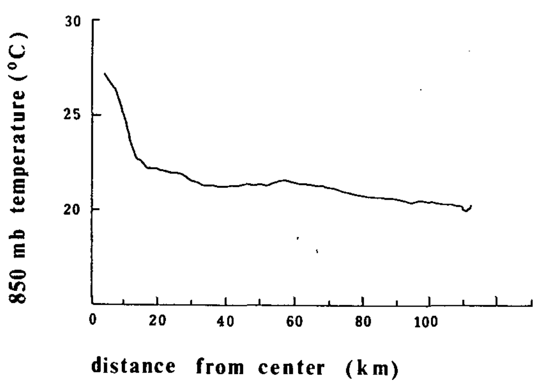


FIG. 2. Hurricane Allen 850 mb radial temperature profile, 1143–1724 GMT 8 August 1980. This is an azimuthal average based on 16 passes through Allen by NOAA 43 aircraft. Research Facilities Center. (Courtesy of H. Willoughby, National Hurricane Research Laboratory).

The last of these, Hermine, in late September, returned to a mostly westward track.

Wagner (1980) describes a substantial weakening of the Atlantic subtropical 700 mb ridge in mid-August. This may be causally related to the difference in track between Allen and Bonnie, to the extent that large-scale steering currents are correlated to the intensity of the subtropical ridge.

2. Hurricane Allen, 1–11 August

Hurricane Allen was the main event of this season. A classical Cape Verde hurricane, Allen moved westward off the coast of Africa on 29 July as a disturbance associated with a tropical wave. Before reaching the Texas coast almost two weeks later, this hurricane would fluctuate greatly in intensity while crossing the Caribbean Sea and Gulf of Mexico.

St. Lucia, Haiti and the United States experienced a large measure of this storm's intensity, and half a dozen other Caribbean island countries were also seriously affected, as the dangerous hurricane eye passed menacingly close.

a. *Intensity*

Fig. 3 is a graph of Allen's minimum sea level pressure as a function of time. This figure is based on 44 observations by reconnaissance aircraft over a 6-day period beginning late on 3 August, when Allen was approaching Barbados, and ending early on 10 August at the time of landfall in Texas.

Hurricanes sometimes exhibit significant variation in intensity. Lawrence (1979) shows an example of Hurricane Ella (1978). However the amplitude of variation in the case of Allen is quite large. Allen's pressure fluctuated over a 50 mb range, which is 50% of the total observed range of central pressures in Atlantic hurricanes.

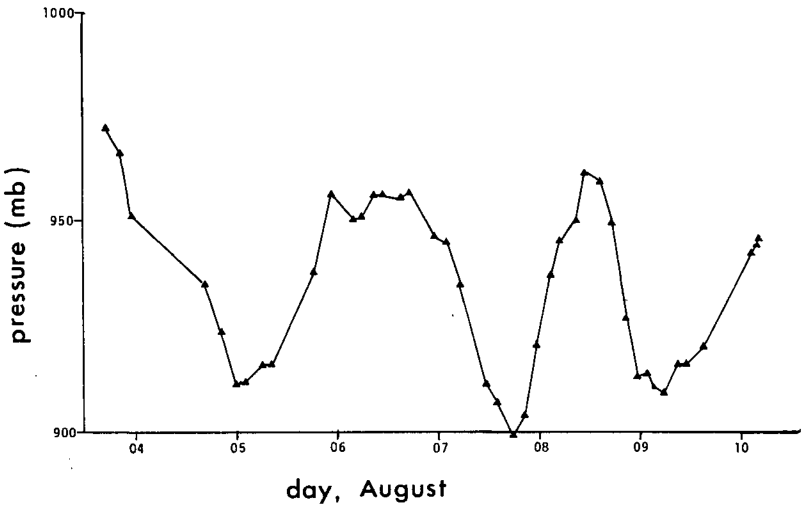


FIG. 3. Hurricane Allen: graph of minimum sea level pressure as a function of time, based on 44 aircraft observations.

Allen's central pressure went through three of these 50 mb cycles in six days. The first fluctuation bottomed out at 911 mb early on 5 August, when Allen was located in the eastern Caribbean, approximately 200 n mi south of Puerto Rico (see Fig. 4).

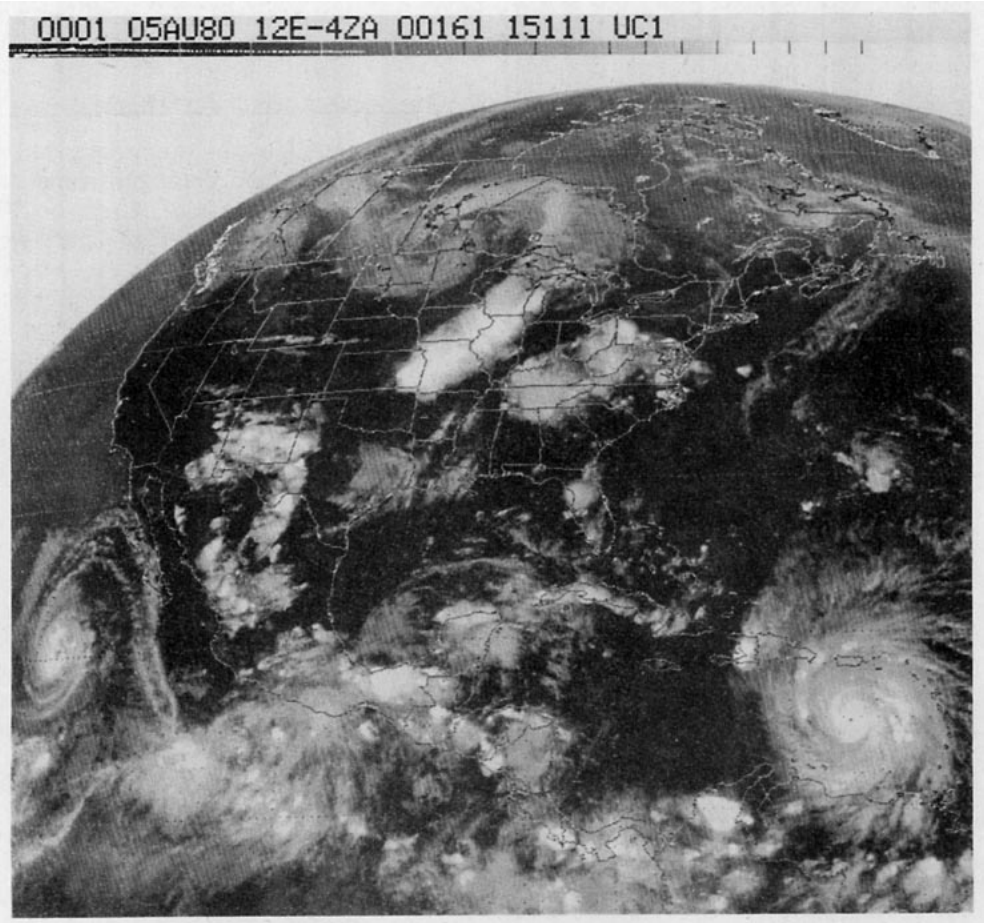


FIG. 4. SMS-2 infrared satellite image at 0001 GMT 5 August 1980. Hurricane Allen is located in the eastern Caribbean and has a minimum sea level pressure of 911 mb. Hurricane Howard, in the eastern Pacific, is present on the far left side of picture.

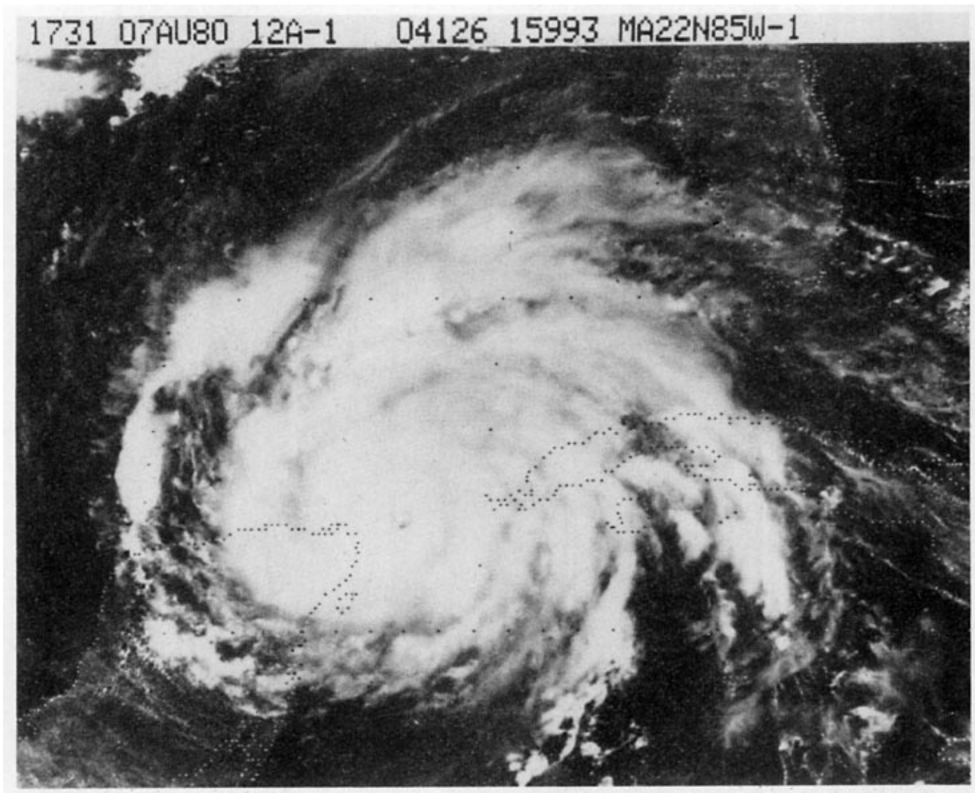


FIG. 5. SMS-2 satellite picture of Hurricane Allen at 1731 GMT 7 August 1980. The 899 mb pressure measurement was made at 1742 GMT.

The next pressure minimum was measured at 1742 GMT 7 August, when the storm center was moving through the Yucatan Channel into the Gulf of Mexico. An aircraft dropsonde measured 899 mb. This is the second lowest hurricane surface pressure in modern records for the Atlantic–Caribbean–Gulf of Mexico area, surpassed only by the 892 mb value mentioned above. Fig. 5 shows a visible satellite picture of Allen centered in the Yucatan Channel within minutes of this record measurement.

Finally, Allen deepened a third time and reached 909 mb early on 9 August in the west-central Gulf of Mexico, within 24 h of landfall on the Texas coast.

Holliday and Thompson (1979) define a rapid deepening typhoon as one whose deepening rate is greater or equal to 45 mb day^{-1} or 1.75 mb h^{-1}, for 24 h. Allen's rate of deepening exceeds this criterion during all three periods of intensification shown in Fig. 3. Fig. 6 shows Allen located in the western Gulf of Mexico at 1803 GMT 8 August, when the deepening rate averaged out to 4.0 mb h^{-1} over the 12 h period centered at this time.

This discussion of storm intensity has concentrated on minimum sea level pressure as the measure of intensity. In fact, it is the maximum surface wind speed which is of more practical concern, but measurements of this quantity are, at best, difficult to obtain. However, the two—wind speed and central pressure—are highly correlated and empirical relationships have been established between them. Atkinson and Holliday (1977) give a review of this subject.

The estimated maximum sustained (1 min average) surface wind speed in Allen is 165 kt, during the time of the 899 mb pressure observation. Numerous measurements of wind speeds in excess of 150 kt were taken by various reconnaissance flights during the course of the storm. For example, at 1319 GMT 5 August, a NOAA research aircraft, flying at an altitude of 500 m, measured a 10 s average wind speed of 155 kt. This occurred ~40 km northeast of the storm center which was located to the south of the Dominican Republic at the time.

b. *Allen's track*

Allen was tracked with satellite data from the time of its inception in the far eastern Atlantic on 29 July. Aircraft reconnaissance missions began on 3 August and continued until landfall. Radar fixes were occasionally available as the storm moved within range of the several radars along its path. During the six days of reconnaissance, 72 eye pen-

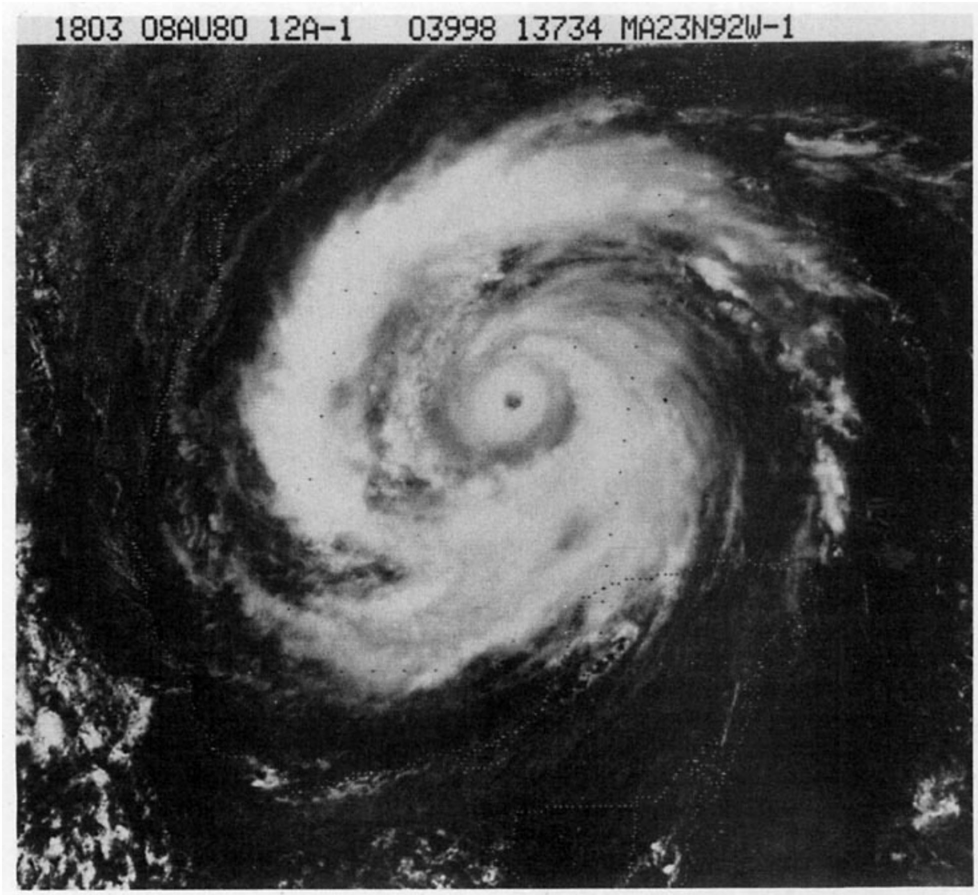


FIG. 6. SMS-2 satellite picture of Allen at 1803 GMT 8 August 1980.

etrations were accomplished, resulting in an average of one vortex fix every 130 min.

Storm motion (direction and speed) was also calculated every 6 h. The average direction of motion for the ten day period is toward a heading of 289° with a range of 267–308°. This is a very steady directional movement. In spite of this steadiness, the storm managed to weave its way among a number of island countries in the Caribbean, so that the eye always remained over water.

Allen's speed of movement ranged from 18 to 22 kt across the Atlantic and eastern Caribbean. It gradually decelerated beginning on 7 August while centered just south of Cuba, in response to surface pressure falls across the southeastern United States. A minimum forward speed of 6 kt was reached late on 9 August, just prior to landfall.

c. *Impact in the Caribbean*

The eye of the storm passed just north of Barbados and then just south of St. Lucia in the Windward Islands early on 4 August. Rapid deepening was occurring and minimum surface pressure was near 950 mb when the south portion of the eyewall passed very close to extreme northern Barbados at 0000 GMT 4 August. The highest measured wind was only 68 kt at the airport on the south side of Barbados, far from Allen's strongest winds. On the north side of the island, there were no wind measurements, but a 950 mb hurricane is likely to have winds of 100 kt or higher under the eye wall. Local officials estimate damage at U.S. $6 million, primarily to agriculture, private housing and the fishing industry. No deaths were reported.

A few hours later, the more dangerous north portion of the eyewall swept across southern St. Lucia. Sustained winds of 90 kt and a sea level pressure of 967 mb were reported from Hewanorra, a weather station in this area. It is expected that hurricane force winds affected most of the island. Damage to St. Lucia's housing, agricultural and industrial sectors is estimated at $235 million and six deaths have been attributed to the storm.

St. Vincent, only 30 n mi south southwest of St. Lucia, experienced the outer southern fringes of the storm. Torrential rains caused damage to agriculture.

Allen moved across the open waters of the eastern Caribbean on 4 and 5 August, deepening to 911

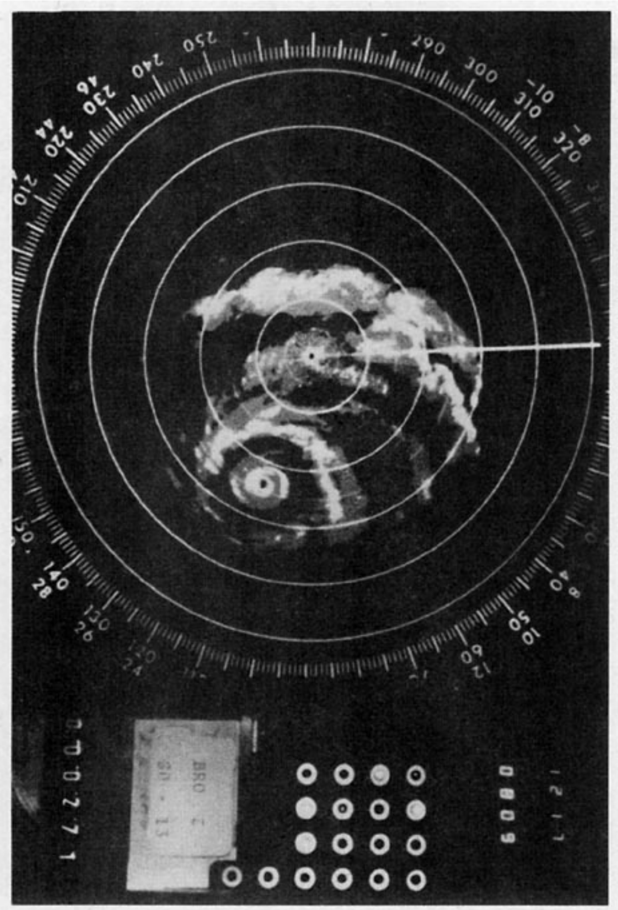


FIG. 7. Brownsville, Texas radarscope at 1217 GMT 9 August 1980, showing Allen's well-defined eye structure. (North is to the right.)

mb and then weakening. As the central pressure was climbing through 940 mb, late on 5 August, the eye grazed the southwest tip of Haiti. There have been no meteorological reports, but Haitian officials report 220 deaths and a damage estimate of $400 million.

Shortly thereafter, early on 6 August, the north coast of Jamaica was seriously affected by the storm, which moved between Jamaica and eastern Cuba. As the pressure rose to 955 mb, Allen caused eight deaths and $100 million in damages in Jamaica. Storm surge and wave action battered structures at elevations of 20 ft along the northeast coast of Jamaica. Rainfall amounts of 10–20 inches were also reported.

Some incomplete information has been received concerning a ship lost at sea. The *Georgios G*, a Panamanian freighter, departed Santa Domingo, Dominican Republic on the evening of 4 August enroute to Belize City. The ship was in radio contact with another ship early the next day, but was not heard from again. Approximately 25 persons were on board. While the death totals in Table 1 do not include this information, the ship's course appears likely to have been intercepted by the hurricane.

Allen continued into the northwest Caribbean, passing south of southeast Cuba and then almost directly over the Cayman Islands of Cayman Brac and Little Cayman. These small islands suffered heavy damage but no loss of life.

Allen reintensified on 7 August. As the center passed 60 n mi south of the Isle of Pines, the pressure was 930 mb and falling. The center, now at 910 mb, passed within 40 n mi of Cape San Antonio and the western tip of Cuba experienced hurricane conditions.

Moving through the Yucatan Channel, Allen reached its 899 mb record intensity. It moved rather close to the northeast tip of the Yucatan Peninsula at this same time.

d. Landfall

As Allen moved across the southwest Gulf of Mexico, its intensity fluctuated for the third and final time. Fig. 7 shows a Brownsville radar picture of Allen, when the center was 100 n mi off the coast. The pressure was 916 mb and rising at this time. Note the appearance of a double, inner and outer eye.

The eye crossed the Texas coast at 0600 GMT 10 August just north of Brownsville. The central pressure was up to 945 mb and maximum sustained winds were near 100 kt. Allen continued inland, dissipating over the mountainous terrain of northern Mexico.

Hurricane warnings were issued midday on 8 August for the Texas coast from Brownsville to High Island (near Galveston). Decelerating forward motion delayed landfall, allowing ample time for precautionary actions.

Table 2 contains available meteorological data along the Texas coast. The eye crossed over an undeveloped part of Padre Island, and moved inland between Brownsville and Port Mansfield. A maximum gust of 68 kt was reported at the Brownsville airport and a 104 kt gust was reported at Port Mansfield. The storm surge height at Port Mansfield was 12 ft msl, even though astronomical tides were quite low. Even higher storm surge values occurred along Padre Island, where the brunt of Allen's wind and storm surge was directed. More than 60 washover channels have been counted and the first line of sand dunes was wiped clean along a desolate part of this barrier island.

There were 29 documented tornadoes associated with this storm. Some of the more severe tornadoes formed on the afternoon of 10 August, along a spiral rain band, 150–200 n mi north of the center. This includes an area from east of San Antonio to San Marcos to Austin.

TABLE 2. Hurricane Allen landfall observations, 9–10 August 1980.

Location	Date	Pressure (mb)	Minimum time[a]	Maximum wind (kt) Sustained	Time[a]	Gust	Time[a]	Tide height (ft) above-normal	Rainfall (inches)
Texas									
Adams Gardens									8.36
Alice									15.65
Aransas Pass	10	994.2	0400	E54	1200	92	0845	7.5	17.40
Beeville									13.31
Brownsville	9			N42	2252	N68	2233		
Brownsville	10	968.5	0545						6.92
Corpus Christi	10	991.5	1058	ESE47	1055	ESE80	1020	8.9[b]	10.26
Corpus Christi Naval Air Station	10							9[c]	8.79
Edinburg									14.51
Falfurrias									12.49
Galveston	10	1006.7	0700	22	0700	37		5[c]	
Georgewest									13.09
Houston	9			E28	1755	ESE33	1954		
Houston	10	1008.5	0650						
Kingsville									11.22
McAllen									12.60
McCook									6.29
Mercedes									5.96
Mission									6.81
Port Arthur	09			E23	1853	E33	1918		
Port Arthur	10	1009.4	0957						
Port Mansfield	10					104			
Port Oconnor	10	1005.4	1200			68		4.5	
Raymondville		969.9	1200						7.14
Rio Grand City									1.75
San Antonio	10	977.0	2053			39			1.59
Santa Rosa									4.49
South Padre Island	10							7.9 0600	
Victoria	10	1000.0	0955	22		40	1202		
Louisiana									
Lake Charles	10	1010.5	0915	E18		E26		3	

[a] Greenwich Mean Time.
[b] Height above mean low water.
[c] Estimated.

Rainfall totals indicate a 15–20 inch rainfall maximum along a swath 50–100 mi inland and parallel to the south Texas coast. This caused severe local flooding.

Allen's core region of maximum intensity swept over a rather remote section of coastline between the two population centers of Brownsville and Corpus Christi. Even so, there was an estimated $300 million in damages in Texas, as well as two deaths. Two offshore oil rigs in the Gulf of Mexico were destroyed and 13 persons perished in a helicopter crash during an oil rig evacuation. Evacuation estimates range up to one-half million persons along the coast of the northwest Gulf of Mexico.

3. Other named storms

a. Hurricane Bonnie, 13–19 August

Cloudiness associated with a tropical wave became rather well-organized on 13 August and by 0000 GMT 14 August a depression had formed ~700 n mi west of the Cape Verde Islands. A ship (GYHC) passed directly through the developing system later that day and radioed reports of winds increasing to Beaufort force 9 (44 kt) and 999.9 mb sea level pressure, which indicates tropical storm intensity.

Simultaneously, a second depression was forming only 400 n mi northeast of Bonnie. Bonnie was the dominant system and headed northward. The depression moved northwestward and dissipated. This area is devoid of coventional data and Bonnie's northward motion was not anticipated as there existed a surface high-pressure ridge to the north and the previous storm, Allen, had moved primarily toward the west.

Nevertheless, Bonnie did not deviate much from a due north course as it traveled 1200 n mi northward. Hurricane force was attained early on 16 August, based on satellite intensity estimates. Fig. 8

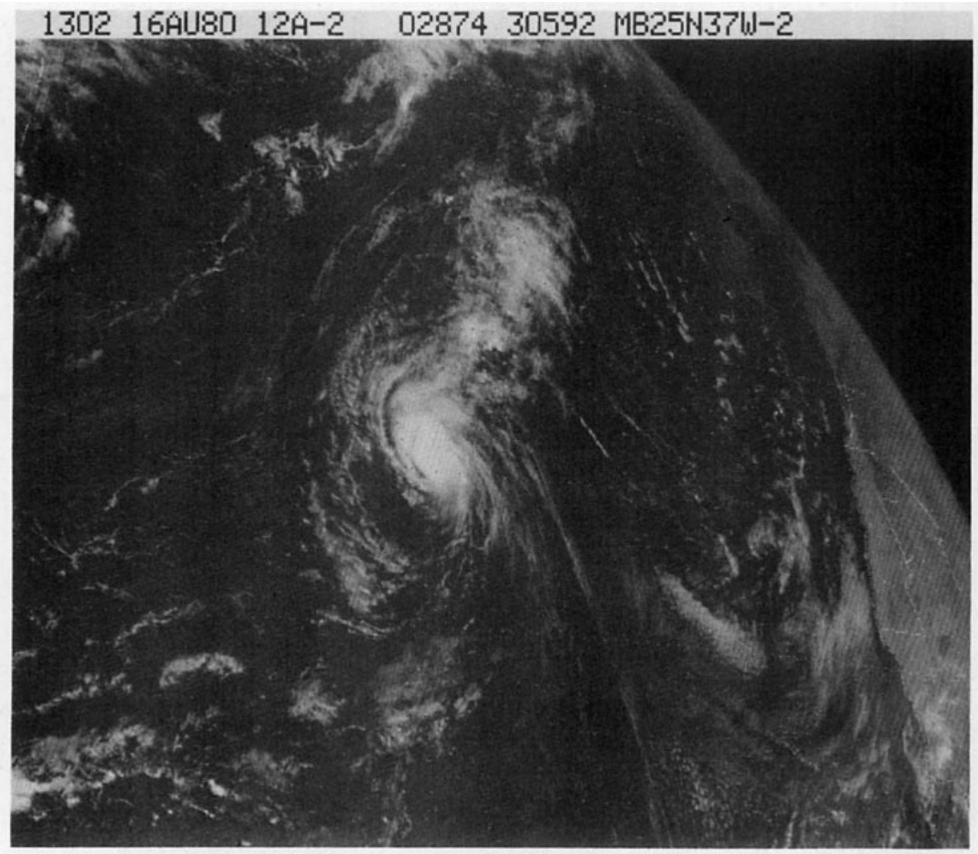


FIG. 8. SMS-2 satellite picture of Hurricane Bonnie at 1302 GMT 16 August 1980.

shows a satellite picture of Bonnie at the time that the maximum wind speed was estimated at 85 kt. The storm continued northward out of the tropics, maintaining the appearance of a minimal hurricane for several days. On 19 August it moved north of 50°N and became extratropical.

b. Hurricane Charley, 20–25 August

Charley originated from an extratropical low-pressure system which had moved southeastward over the U.S. mid-Atlantic coast on 20 August. By midday, satellite pictures showed that a well-defined low-level cloud circulation center was positioned just offshore from Hatteras, North Carolina. Fig. 9 shows the incipient vortex, located to the north of cloudiness which had earlier been identified as a cold front.

However, sea-surface temperatures were near 27°C in the vicinity of the vortex, and gradual intensification occurred. The system moved in a cyclonic loop for three days, under the influence of the larger extratropical cyclonic circulation which was controlling its motion. The hurricane track chart (Fig. 1) shows that Bonnie evolved through the stages of subtropical depression and subtropical storm prior to reaching hurricane status. The center passed within 200 n mi northwest of Bermuda, where the pressure dropped to 1003.3 mb at 0600 GMT 22 August. Six hours later a ship just north of the center reported 999.5 mb and 60 kt winds. An Air Force reconnaissance plane investigated on the following day and measured a surface pressure of 989 mb along with 70 kt estimated surface winds. These data form the basis for estimating Charley's maximum intensity. Fig. 10 shows a satellite picture of the hurricane during the time of its maximum strength.

By 24 August, Charley was moving due eastward and accelerating its forward speed, which reached 45 kt by 25 August. The storm gradually weakened and was no longer identifiable as a tropical weather system by 26 August, having finally become absorbed by an intense North Atlantic extratropical cyclone.

Charley passed directly across the North Atlantic shipping lanes on 24 and 25 August and numerous ships reported gale-force winds during this period.

c. Tropical Storm Danielle, 4–7 September

A tropical wave crossed the African coast on 22 August and briefly became a depression in the mid-Atlantic five days later. The surviving wave contin-

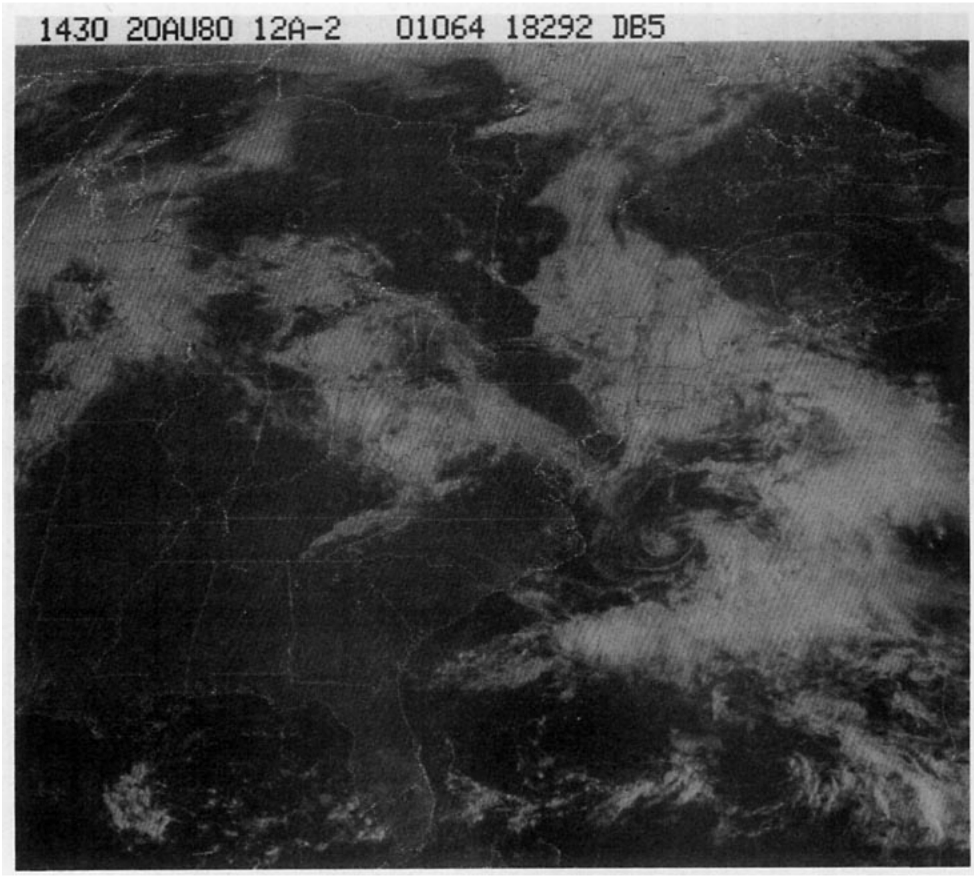


FIG. 9. SMS-2 satellite picture of cloud vortex which developed into Hurricane Charley. Vortex is centered to east of North Carolina. Time is 1430 GMT 20 August 1980.

ued westward and interacted with a mid-tropospheric low on 2 September, producing disturbed weather over Florida and adjacent waters.

A low-level circulation developed and a depression formed on 4 September, centered near the southeast Louisiana coast. It slowly intensified and became Tropical Storm Danielle only hours before crossing the coast in the Galveston Bay on the evening of 5 September. Its remnants were tracked inland for two days, reaching the Rio Grande Valley near Del Rio on 7 September.

Oil rigs, ship reports and reconnaissance flights indicate that Danielle reached maximum intensity on 5 August, prior to landfall, with a minimum surface pressure of 1004 mb and maximum sustained winds of 50 kt. The lowest pressure reported on land was 1008 mb at Galveston. A satellite picture of Danielle near the time of landfall is shown in Fig. 11.

Tides were 2–3 ft above normal on the southwest Louisiana and upper Texas coasts. Danielle's main impact was inland flooding from heavy rainfall spreading westward across Texas. A 25-inch rainfall was reported near Junction, Texas. The Beaumont airport established a new 24 h record of 17.16 inches. Major metropolitan flooding occurred in the Beaumont-Port Arthur area, requiring some evacuation. One death was caused in Beaumont when an automobile was driven past a barricade into 15 feet of water.

d. Hurricane Earl, 4–10 September, Hurricane Frances, 6–20 September and Hurricane Georges, 1–8 September

A series of three waves began to move off the African coast on 28 August. The first of these continued across the Atlantic, recurving west of Bermuda, and eventually strengthening to Hurricane Georges. Meanwhile, the following two waves recurved farther to the east and developed into Hurricanes Earl and Frances.

Earl reached tropical storm strength on 4 September while centered 100 n mi northwest of the Cape Verde Islands. It continued at storm strength for several days, and turned to the north by 7 September. Satellite pictures revealed an eye-type feature

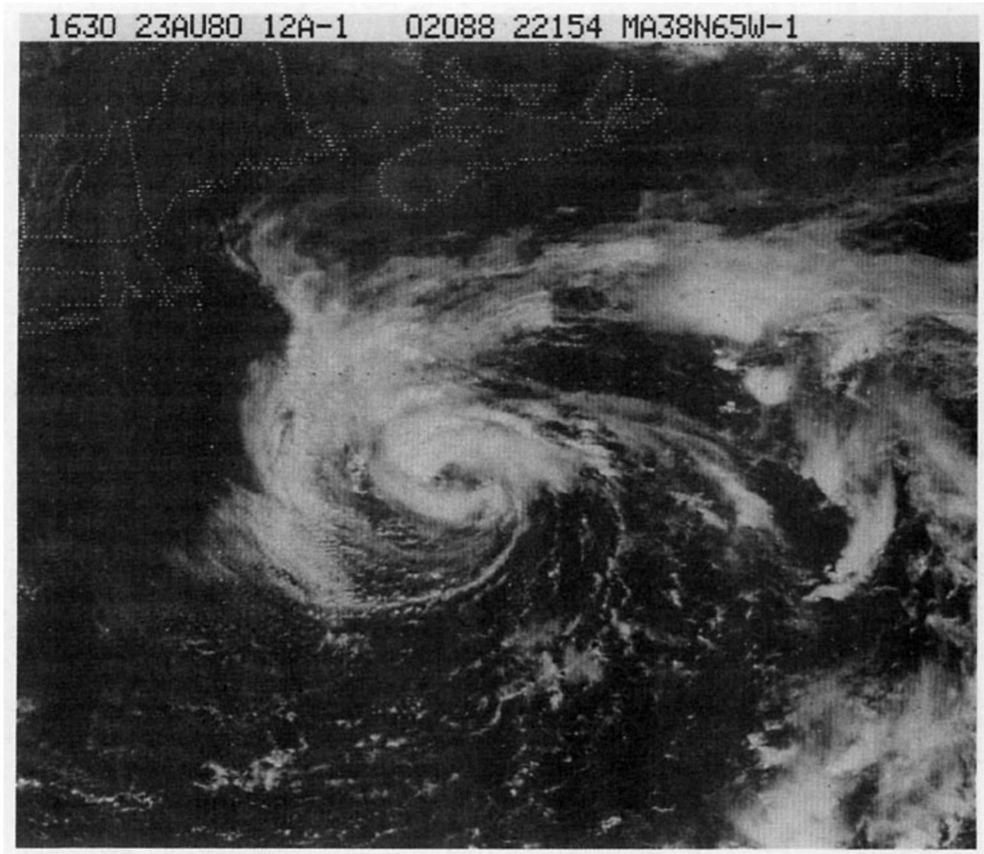


FIG. 10. SMS-2 satellite picture of Hurricane Charlie with a minimum sea level pressure of 989 mb. Time is 1630 GMT 23 August 1980.

on 8 September and based on satellite intensity estimates, it remained a minimal hurricane with 65 kt winds for two days. On 10 September, accelerating toward the northeast, Earl became extratropical over the far North Atlantic.

Frances followed directly after Earl, with a lag of 2–3 days, and displaced to the south ~ 300 n mi. It became a storm at 1800 GMT 6 September and reached hurricane force 30 hours later, while crossing the twenty-fifth meridian just south of the Cape Verde Islands. Frances remained a hurricane for 12 days as it turned northward across the central North Atlantic. Hurricane Ginger in 1971 was the last storm to remain a hurricane for 12 or more days (Ginger was a hurricane for 19 days). Maximum intensity is estimated at 100 kt on 9 September and wind speeds were in the 80–90 kt range for much of the hurricane's duration.

Returning to the wave of 28 August, this system was tracked as a depression from 1–4 September, but it weakened as it passed northwest of the Leeward Islands. The residual disturbance interacted with an upper level cold low and formed a subtropical depression on 5 September. Fig. 11 shows a picture of this depression, centered 300 n mi southwest of Bermuda.

The depression moved northeastward, separated from the upper low and slowly acquired a more tropical appearance. On 7 September, it reached storm strength and 24 h later, Georges became a hurricane. The center passed 100 n mi southeast of Cape Race, Newfoundland on 8 September and the storm began to dissipate later that day. Maximum winds are estimated at 70 kt at 0000 GMT 8 September.

It is of interest that within a 24 h period centered at 1200 GMT 8 September, all three hurricanes—Earl, Frances and Georges—reached their maximum intensity. Fig. 12 is a visible satellite picture at this time showing all three storms.

e. *Tropical Storm Hermine, 20–25 September*

Hermine moved off the African coast as a tropical wave disturbance on 11 September. It moved westward, uneventfully, across the Atlantic for five days. But on 17 September, a few hundred miles east of the Lesser Antilles, the satellite-observed

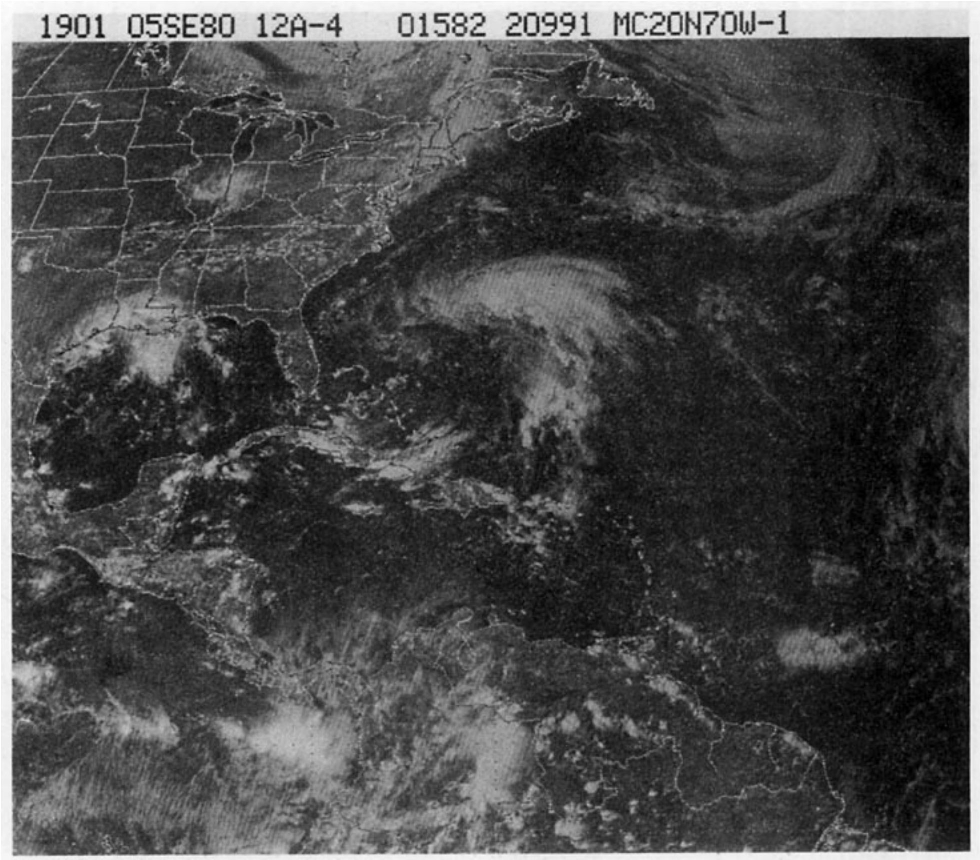


FIG. 11. SMS-2 satellite picture of Tropical Storm Danielle at 1901 GMT 5 September 1980. The disturbed area centered several hundred miles east of Jacksonville became Hurricane Georges three days later.

cloud features appeared to become better organized. There was low-level cloud banding and increased convection around an apparent circulation center. However, the system was moving at 15–20 kt and no closed circulation was detected by reconnaissance aircraft.

The wave crossed the Lesser Antilles. Island reports of surface pressures were in the 1010–1012 mb range and rainfall amounts were 2 inches or less. The disturbance continued across the Caribbean, passing to the south of Jamaica on 20 September. At this time, there was a change in cloud structure with more concentrated convection and better defined low-level cloud circulation. Intensification continued and minimal tropical storm intensity was attained at 0600 GMT of the next day, when the center was located barely 80 n mi east of eastern Honduras.

Hermine brushed the northeast coast of Honduras and reached Belize at 1200 GMT 22 September, just north of Belize City which reported 999 mb and west winds gusting to 36 kt. Belize City's radar indicated a poorly defined center at this time. Just before landfall, an Air Force flight measured a minimum pressure of 995 mb, and maximum winds were estimated at 60 kt. Fig. 13 shows the storm only several hours after landfall.

The storm crossed the Yucatan Peninsula and moved over the Bay of Campeche on 23 September. Weakening occurred over land and winds dropped to 45 kt. However, 60 kt winds were reached again as Hermine strengthened over the waters of the Gulf of Mexico. A reconnaissance measurement of 993 mb was made early on 24 September. These figures, 60 kt and 993 mb, represent Hermine's maximum intensity.

In the Bay of Campeche, Hermine's course changed from west-northwest to southwest as its forward speed decreased. Landfall occurred at 1200 GMT 24 September, 90 n mi southeast of Vera Cruz. The storm drifted inland, became stationary, and dissipated over Mexico two days later.

When Hermine first emerged over the southern Gulf of Mexico after crossing the Yucatan Peninsula, the forecast was for a continuation of a west-northwest track, possibly turning more northward and threatening the upper Mexican or Texas coast. This was unanimously supported by various objec-

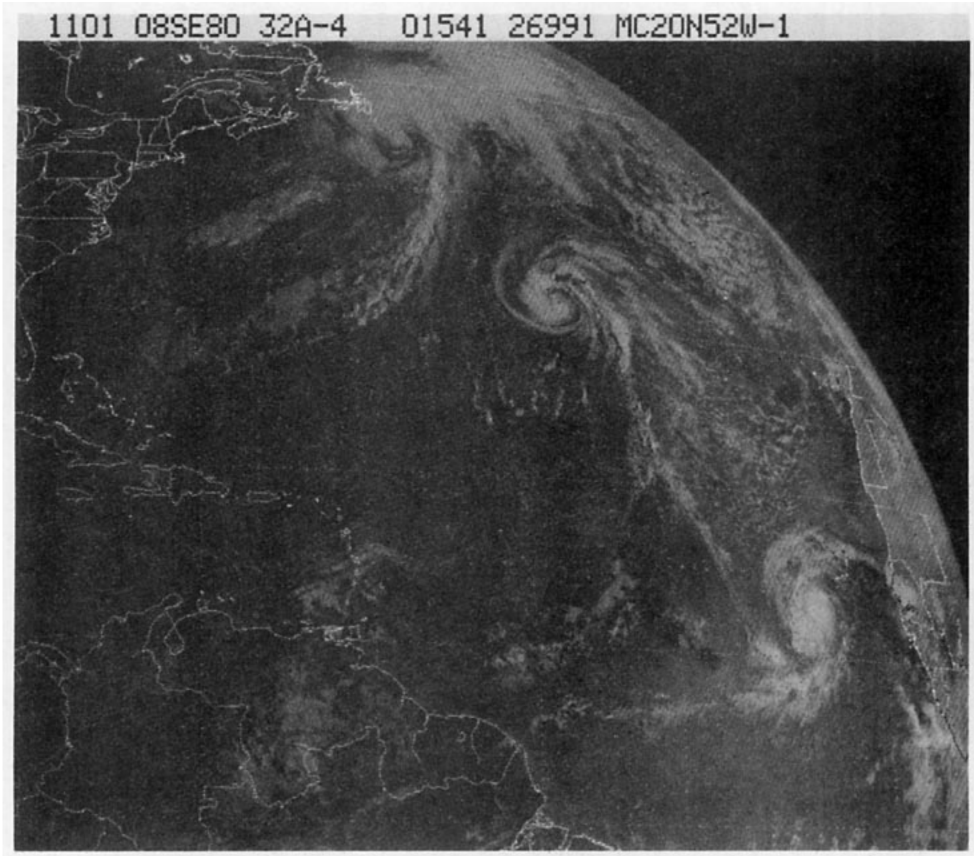


FIG. 12. SMS-2 satellite picture of three hurricanes—Georges is at upper left, Earl is in the middle and Frances is at lower right. Time is 1101 GMT 8 September 1980.

tive guidance techniques. Even after the turn toward the southwest had been detected and incorporated into the initialization of the forecast models, many of the guidance techniques persisted in forecasting a turn to the north. This suggests that statistical, as well as dynamical, tropical cyclone motion forecast techniques become less accurate near the areal boundaries of their data bases.

There were news reports of severe freshwater flooding in southern Mexico and it is likely that flooding also occurred over portions of Honduras and Belize.

f. Hurricane Ivan, 1–11 October

On 27 September, a low pressure system moved southward to a position off the southwest coast of Portugal. By 1 October, it was centered between the Azores and Canary Islands. The system extended from the surface upward throughout the troposphere and was of extratropical origin. Satellite pictures showed marked cyclonic banding of the associated cloudiness, but little convection near the center, a feature identified with cold-core circulations.

The low moved in a clockwise loop during 2–4 October and convection gradually increased near the circulation center suggesting a change to tropical structure. Ivan reached tropical storm strength at 1600 GMT 4 October and increased to hurricane force on the following day, while moving southwestward. Winds increased to a 90 kt maximum on 6 October and this intensity was maintained for four days. Fig. 14 shows a view of Ivan on 6 October, with a very well defined center.

Ivan then executed a counterclockwise loop followed by west-north-west motion. On 9 October it began turning toward the northeast and merged with an extratropical low and frontal system two days later.

It is of interest that sea-surface temperatures were only about 23°C during the time that transformation to a tropical system occurred. As stated in the Introduction, the dynamics of such events are not well understood.

g. Hurricane Jeanne, 7–16 November

Disturbed weather had persisted over the northwest Caribbean since 4 November, at which time

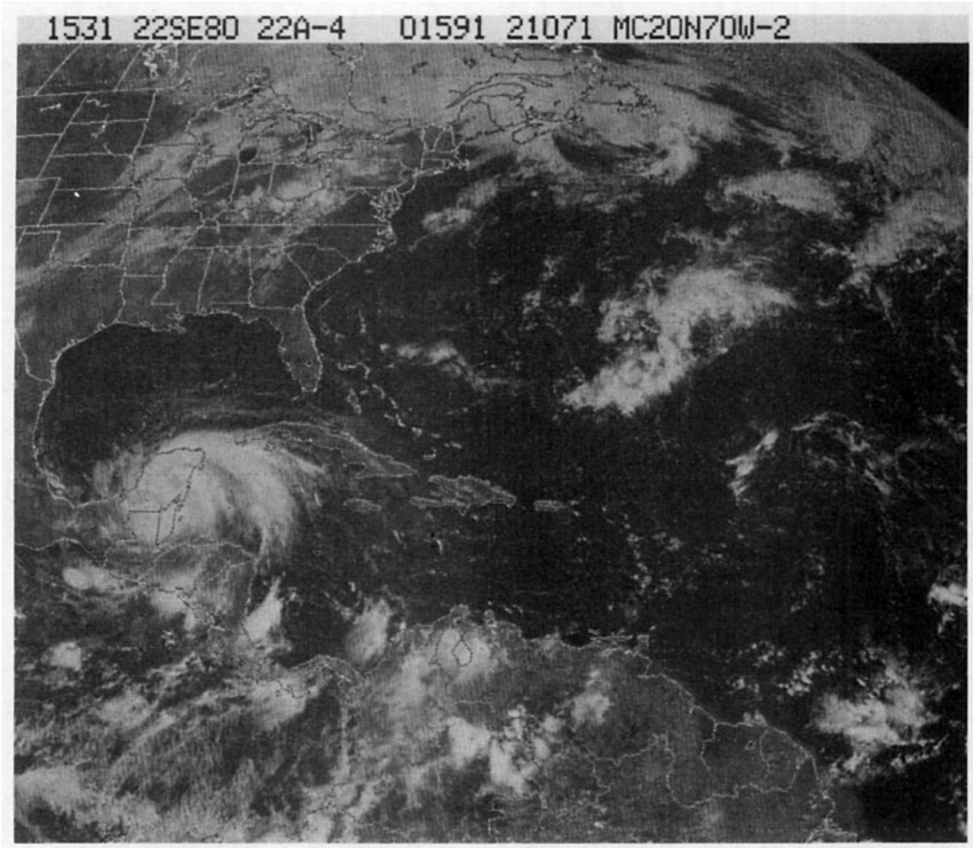
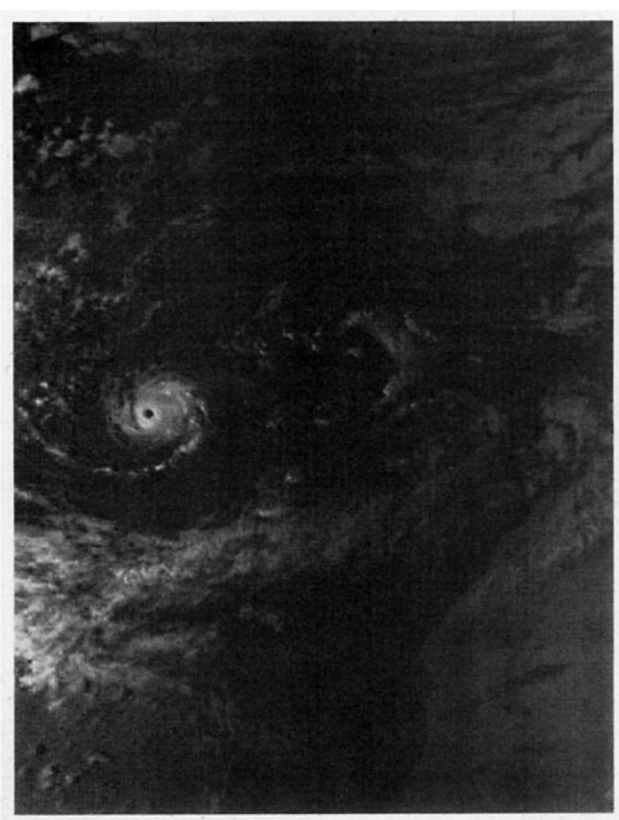


FIG. 13. SMS-2 satellite picture of Tropical Storm Hermine moving across the Yucatan Peninsula. Time is 1531 GMT 22 September 1980.



a tropical wave moved into the area. A depression formed within this weather area on 8 November. It moved northward into the Yucatan Channel on the next day and became a tropical storm with a surface pressure of 999 mb and 45 kt winds. The northwest Caribbean is a preferred region for development of both early and late season storms.

Several ships were caught by surprise by this unseasonably late storm and an oil rig tender barge with 16 persons aboard was carried along near the storm center for several hundred miles. Jeanne strengthened to a hurricane on the morning of 11 November and reached its maximum intensity later that day when a Coast Guard vessel reported 95 kt winds. Fig. 15 shows a picture of Jeanne in the east central Gulf of Mexico when the surface pressure was 986 mb. The center is seen to be obscured by a dense overcast.

Meanwhile, on the storm's fringe, a record-breaking rain deluged Key West. During the 24 h period centered on 1800 GMT 11 November, 23.28 inches were recorded.

Jeanne reverted to tropical storm status late on

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FIG. 14. Satellite picture of Hurricane Ivan at 1642 GMT 6 October 1980.

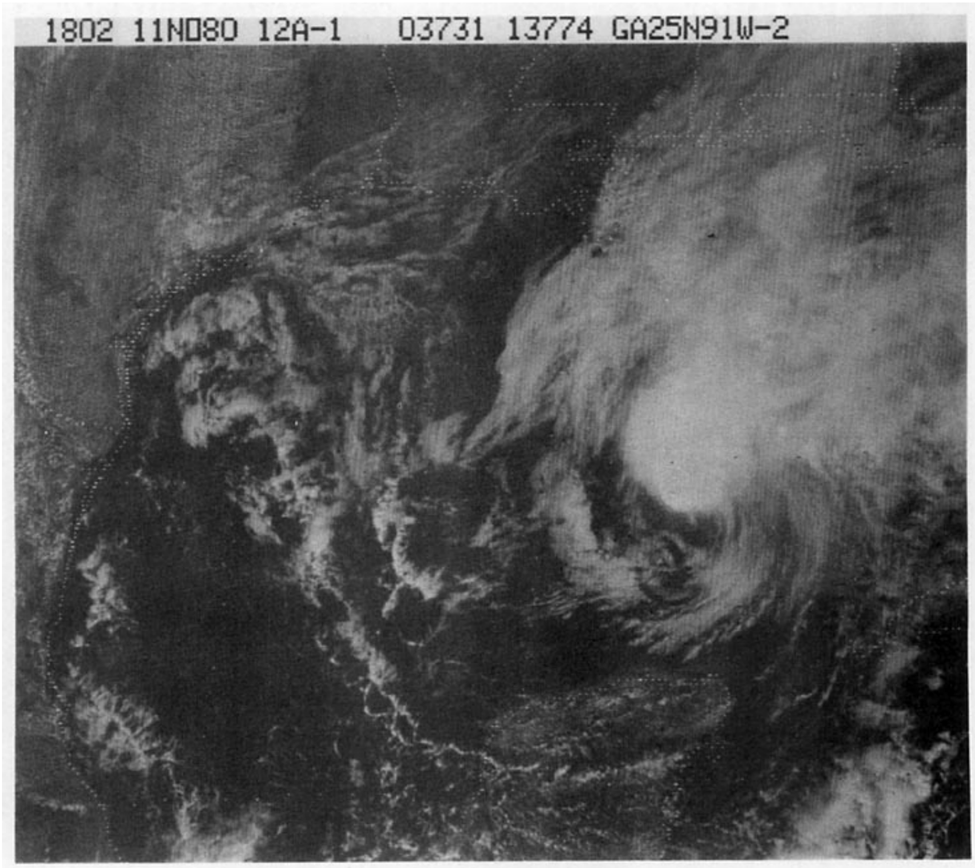

FIG. 15. SMS-2 satellite picture of Hurricane Jeanne at 1802 GMT 11 November 1980.

12 November and then proceeded to drift, describing a clockwise loop across the western Gulf of Mexico for several days. A cold front entered the Gulf on 14 November and this interacted with the storm, causing it to weaken to a depression. The depression dissipated at sea on 16 November.

Tides of 2–4 ft above normal occurred along the Texas coast, accompanied by minor beach erosion. Finally, it is notable that there have been only three hurricanes this century in the Gulf of Mexico during the month of November.

h. Hurricane Karl, 25–27 November

A Hatteras-type low pressure system developed along a frontal zone near the southeast United States on 21 November. This low moved to just south of the Canadian Maritime Provinces by 1200 GMT 22 November, intensifying to below 1000 mb and 50 kt winds.

The low reached a position several hundred miles south of Cape Race, Newfoundland on 24 November. By this time the system had become quite large, carving out a surface circulation of over 600 n mi radius. A frontal occlusion process had also been in progress and this resulted in the appearance of a rather homogeneous air mass near the circulation center; cloudiness was suppressed and the horizontal temperature gradient was weak with ship-reported air temperatures and sea surface temperatures near 20°C.

Early on 25 November, satellite pictures showed that a circular convective cloud mass about 100 n mi in diameter had formed near the low center. The eye was well-defined, implying that a small tropical system had developed within the larger extratropical cyclone.

Satellite intensity estimates were at 65 kt—minimal hurricane force—by 1800 GMT of that day, at which time the system was centered 600 n mi west southwest of the Azores. Given the name Karl, the hurricane strengthened slightly for the next 24 h. The central cloud mass became separated and distinct from the surrounding baroclinic cloudiness. Karl's maximum intensity is estimated at 75 kt for the period 0600–1800 GMT 26 November. A corresponding minimum sea level pressure of 985 mb is assigned based on empirical pressure-wind relationships. Fig. 16 is a picture of Karl during this time.

When Karl was intensifying to a hurricane, its track described a very small cyclonic loop. Karl was apparently rotating within the larger scale cy-

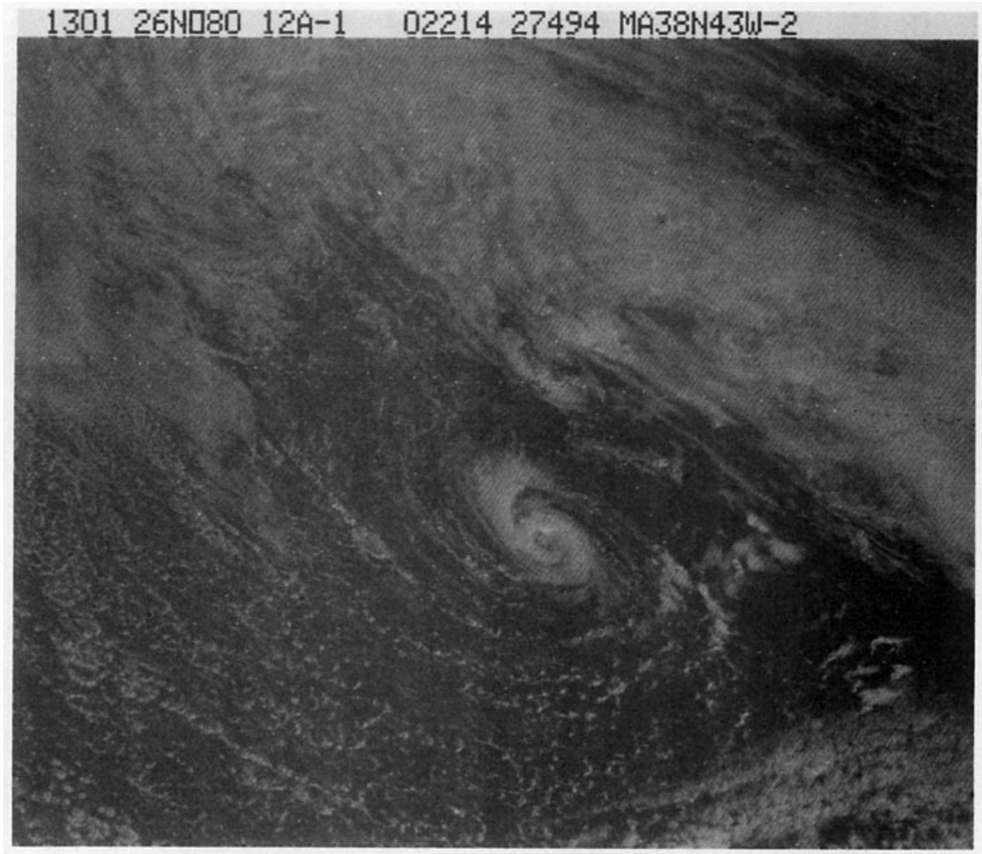

FIG. 16. SMS-2 satellite picture of Hurricane Karl at 1301 GMT 26 November 1980.

clone within which it was embedded. A major trough moved eastward from North America and developed into the primary cyclonic circulation over the North Atlantic. Karl responded with a large cyclonic turn—first toward the east and then northward—around the periphery of the new low to its west.

The center of Karl passed within 200 n mi of the western-most Azores on 27 November, but had little impact on these islands. A ship came within 60 n mi northwest of the center at this time and reported a 993 mb sea level pressure, but only 30 kt winds. Late on this same day, the central cloud features were becoming less distinct, indicating weakening. Karl was moving northward by 28 November and it merged with frontal cloudiness associated with the approaching extratropical cyclone.

There have been several North Atlantic November hurricanes during this century, but none have been observed so far east in the Atlantic during the last 10 days of the month.

Acknowledgments. Portions of this material were prepared by G. B. Clark, P. J. Hebert and J. R. Hope. Mary Watson assisted with the hurricane track chart.

REFERENCES

Atkinson, Gary D., and Charles R. Holliday, 1977: Tropical cyclone minimum sea level pressure/maximum sustained wind relationship for the western North Pacific. *Mon. Wea. Rev.*, **105**, 421–427.

Holliday, Charles R., and Aylmer H. Thompson, 1979: Climatological characteristics of rapidly intensifying typhoons. *Mon. Wea. Rev.*, **107**, 1022–1034.

Lawrence, Miles B., 1979: Atlantic Hurricane Season of 1978. *Mon. Wea. Rev.*, **107**, 477–491.

Wagner, A. James, 1980: Weather and Circulation of August 1980—Eastward spread of heat wave and drought. *Mon. Wea. Rev.*, **108**, 1924–1932