Atlantic Hurricane Season of 1978

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ABSTRACT

A summary of the 1978 Atlantic hurricane season is presented including detailed accounts of individual storms. There were 11 named storms this year of which five reached hurricane force. Three storms made landfall along the Gulf of Mexico coastline, two in the United States and the other in Mexico. Hurricane Greta affected portions of Central America.

1. General summary

Eleven systems were named as tropical storms during the 1978 hurricane season, and five of these became hurricanes. Tracks and summaries of these storms are given in Fig. 1 and Table 1, respectively. In addition, there was one unnamed subtropical storm during January 1978, also included in the track chart and summary table.

Six of the 11 named storms originated from tropical waves which moved off of the African coast. The other five were initiated as baroclinic developments, i.e., old cold fronts, upper level cold lows, etc.

Comparison of this season's statistics to long-term averages[1] indicates a slightly higher-than-normal number of storms for 1978. In contrast, there were 307 hurricane hours in 1978, where a hurricane hour is counted for each hour that a storm has wind speeds $\geq$ 64 kt. The 30-year average is 620 hurricane hours. Thus, while there were more individual storms than normal, the amount of time during which hurricane-force winds were present was far less than normal.

Inspection of Fig. 1 shows that three tropical storms made landfall along the coastline of the western Gulf of Mexico. Except for extreme rainfall over central Texas from the remnants of Tropical Storm Amelia, there were no other noteworthy events in connection with these storms.

Hurricane Greta raked over the sparsely populated northeast coast of Honduras with 115 kt winds, but the storm's intensity diminished to below 100 kt by the time of landfall in Belize. Limited damage reports indicate that this was not a disastrous storm.

The U.S. East Coast and most of Florida have been spared from a major hurricane for many years, and this year was no exception. It is interesting to speculate on the combined effect of the absence of hurricane activity and the dramatic population increase along our coastline. It is this writer's opinion that the prolonged absence of a major hurricane, in the long run, is not a state of affairs about which a community should be excessively grateful, because the resultant apathy might be a major factor in a future hurricane disaster.

The trend in operational hurricane track forecasting at the National Hurricane Center has been a subject of concern in recent years. It appears that track forecasting has not improved at a rate commensurate with advances in computer technology, satellite observations, etc. Verification statistics for 1978[2] continue to support the notion that, *at best*, forecast accuracy remains on the plateau reached in the early 1970's.

While there is no single, simple explanation for this situation, one topic that appears to be quite relevant concerns the operational analysis of various meteorological fields on the synoptic and hurricane scales, in the vicinity of a given storm.

In particular, the National Meteorological Center's objective analysis of the 500 mb geopotential height fields are of great concern. These fields are used as input data to all of the operational statistical-synoptic and statistical-dynamical prediction schemes for tropical cyclone track forecasting. These are also utilized as the primary synoptic guidance by the hurricane forecaster. Therefore, any degradation of the accuracy of these height fields will have an adverse impact on the prediction schemes.

[1] Neuman *et al.* (1978) gives an annual average of 9.8 storms (of which 6.0 are hurricanes) for the period 1944–77.

[2] A comprehensive evaluation of hurricane forecasting accuracy at the National Hurricane Center is contained in a report compiled by the "*Ad Hoc* working group on research to improve tropical cyclone forecasting," presented to the Interdepartmental Committee for Applied Meteorological Research, NOAA Headquarters, December 1978.

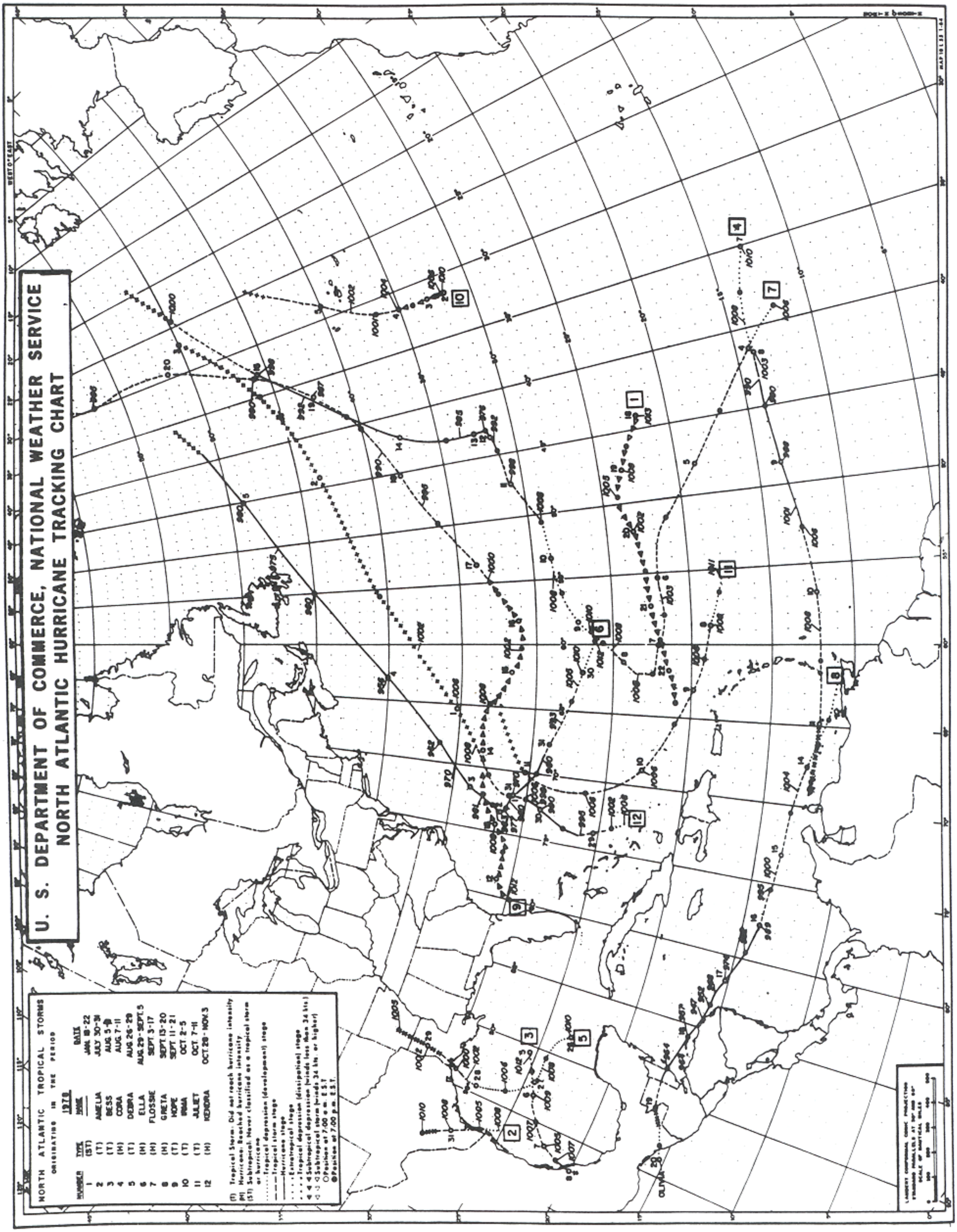

FIG. 1. Tracks of 1978 North Atlantic tropical cyclones.

TABLE 1. Summary of North Atlantic tropical and subtropical cyclone statistics, 1978.

No.	Name	Class*	Dates	Maximum sustained wind (kt)	Lowest pressure (mb)	U.S. damage ($ million)	Deaths
—	—	ST	18–22 Jan	40	1002		
1	Amelia	T	30–31 Jul	45	1005	20	33
2	Bess	T	5–8 Aug	45	1005		
3	Cora	H	7–12 Aug	80	980		
4	Debra	T	26–29 Aug	50	1000		2
5	Ella	H	30 Aug–5 Sep	120	956		
6	Flossie	H	3–16 Sep	85	976		
7	Greta	H	13–23 Sep	115	947		
8	Hope	T	11–21 Sep	55	987		
9	Irma	T	2–5 Oct	45	1001		
10	Juliet	T	7–11 Oct	45	1006		
11	Kendra	H	28 Oct–3 Nov	70	990	minor (Puerto Rico)	1

* T = tropical storm (wind 34–63 kt); H = hurricane (wind 64 kt or higher); ST = subtropical storm (wind 33 kt or higher).

Fig. 2 shows a composite 500 mb analysis of all of the storm cases comprising the dependent data set from which the various statistical forecast techniques were developed. As such, Fig. 2 probably represents, to a first approximation, some average effect of a tropical cyclone on the 500 mb height field.

Fig. 3 is similar to Fig. 2 but is taken from the 1978 operational computer analysis of 78 storm cases. It is quite obvious that the operational 500 mb analysis in the vicinity of a storm does not even remotely represent the storm-scale circulation pattern.

While the reasons for these discrepancies are fairly well understood, and efforts are underway to correct the problem, this has been an intolerable situation in the opinion of this author. Thus, while hurricane forecasting is alive and well, progress is not steady; and at times, it appears that each step forward is accompanied by two steps backward.

2. Individually named storms

a. Tropical Storm Amelia, 30–31 July

1) POST-STORM INLAND RAINFALL

Amelia, a tropical storm whose maximum winds did not exceed 45 kt, will be remembered mainly for the extreme rainfall amounts produced over central Texas.

The storm crossed the south Texas coast late on 30 July and moved northwestward to just west of San Antonio, accompanied by moisture-laden tropical air. During the first few days of August, long after Amelia no longer had a discernable surface low-pressure center, huge rainfall amounts fell over central Texas. The largest totals were reported over the area from San Antonio to Abilene. An amount of 26 inches in 12 h was measured at a location in Shackleford County just northeast of Abilene.

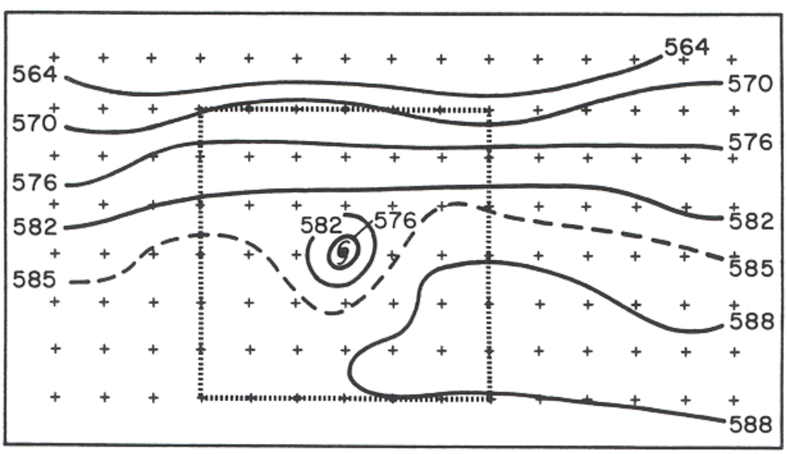

FIG. 2. Composite 500 mb height analysis of 999 tropical cyclone cases from the period 1946–69 on a storm-centered grid. Individual fields were either hand-analyzed or objectively analyzed using a successive-correction scheme. (Courtesy of P. W. Leftwich.)

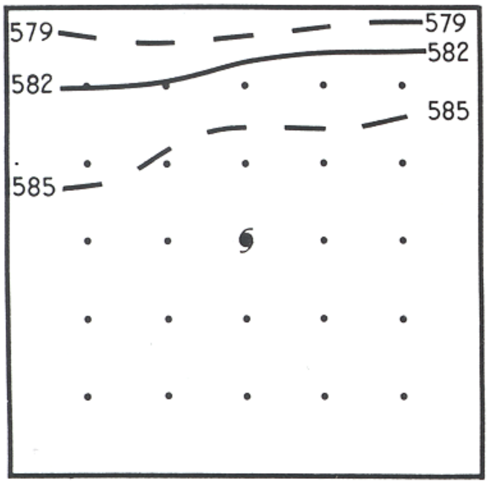

FIG. 3. As in Fig. 2 except for 78 tropical cyclone cases during 1978. Individual fields are from the National Meteorological Center operational computer files. (Courtesy of P. W. Leftwich.)

Amounts greater than 30 inches during the period 1–3 August were measured in Shackleford County as well as to the northwest of San Antonio.

Disastrous flooding occurred in a number of river basins; especially hard hit were the Guadalupe River and its tributaries. There were 33 known deaths in connection with this rainfall and property damage was estimated to be in the tens of millions of dollars.

2) Meteorological history

A tropical wave moved off of the African coast on 19 July, crossing the Atlantic and Caribbean as a weak system without much deep convection. Convection increased on 28 July as the wave approached the Yucatan Peninsula. On the 29th, over the southwest Gulf of Mexico, the cloud system acquired a circular appearance, but without circulation features.

The increase in convection noted above occurred as the wave moved under anticyclonic flow at the 200 mb level. Other features favoring intensification included high (warm) tropospheric thickness values, low vertical wind shear values and warm sea surface temperatures.

A circulation center developed early on the 30th resulting in the designation of this system as a tropical depression. Tropical-storm strength was acquired that afternoon as a reconnaissance flight

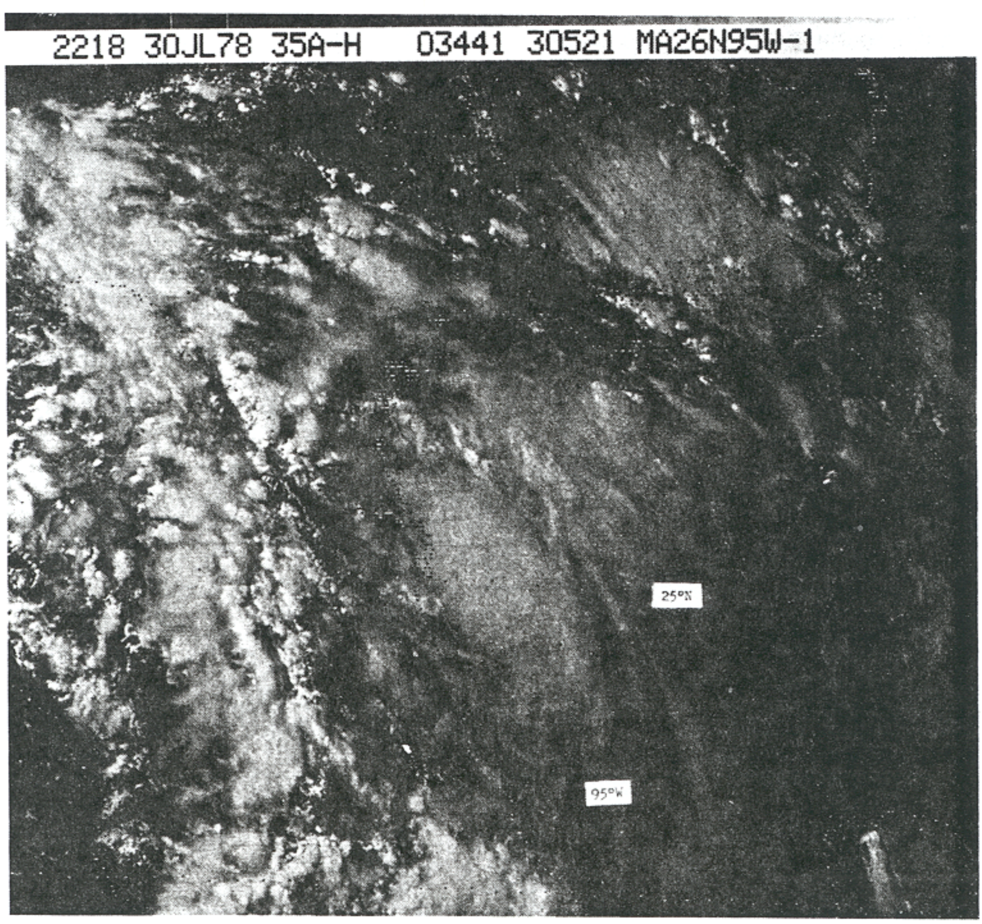

FIG. 4. Visible satellite picture of Amelia at 2218 GMT 30 July 1978 from GOES 3 (½ n mi resolution).

TABLE 2. Meteorological data of Tropical Storm Amelia, 30–31 July 1978.

Station	Date	Pressure (inches) Minimum	Pressure (inches) Time*	Wind (mph) Sustained	Wind (mph) Time*	Wind (mph) Peak gust	Wind (mph) Time*	Tide (ft) Height above MSL	Tide (ft) Time*	Rainfall** (inches)
Texas										
Brownsville WSO	30	29.72	1717	S 39	2304	43	2305			0.37
Corpus Christi WSO	31	29.78	0216	SSE 38	0255	58	0215			3.92
Harlingen substation										0.58
Los Fresnos farm gage										4.01
Padre Island Ranger Station	31					66	0300			
Port Isable										5.15
Port Mansfield Harbormaster	30	29.79				NW 43				4.22
South Padre Island Coast Guard	30					46	1700			

* Central Standard Time.
** Central Texas not included.

measured 45 kt, the storm's maximum sustained wind, along with a minimum pressure of 1005 mb. This situation supported only a poorly defined circulation center. Fig. 4 shows a satellite picture of Amelia just before landfall and during the time of maximum intensity.

The storm center crossed the Texas coast south of Corpus Christi late on the 30th and started to weaken. Brownsville, the closest station to the landfall location, reported sustained winds of 34 kt. A Coast Guard cutter 60 n mi southeast of Corpus Christi reported gusts to 70 kt. Maximum rainfall amounts along the coast were in the 4–5 inch range. Table 2 lists the available meteorological data.

Coastal damage consisted mainly of the sinking of several shrimp boats. There was an undetermined amount of damage to cotton crops. There were no fatalities (except in connection with the inland rainfall as discussed earlier).

b. Tropical Storm Bess, 5–8 August

Bess developed from a weak low-pressure system that formed on a dissipating cold front over northeastern Georgia on 1 August. This low moved south, then southwestward, reaching the extreme northeast Gulf of Mexico on the 3rd. Satellite, buoy and aerial reconnaissance data suggest that a closed circulation formed by 1200 GMT on the 5th in the central Gulf. On the next morning, satellite pictures revealed a well-defined depression, and Bess was designated a tropical storm at 1800 GMT 6 August. Fig. 5 shows a satellite picture at about this time when the storm was located a little more than 200 n mi southeast of Brownsville.

Bess moved slowly across the southwest Gulf of Mexico for the next three days, making landfall near Nautla, Mexico, early on 8 August. (Nautla is approximately 350 n mi south of Brownsville.) The storm's direction of motion, mainly southwest during this time, was under the steering influence of a blocking ridge over south Texas.

Environmental conditions appeared to be favorable for development to a minimal hurricane, but this did not occur. Maximum sustained surface winds reached 45 kt on 7 August with a minimum sea level pressure of 1005 mb. This may be considered as evidence that southward moving storms seldom intensify.

There are no coastal observations available from

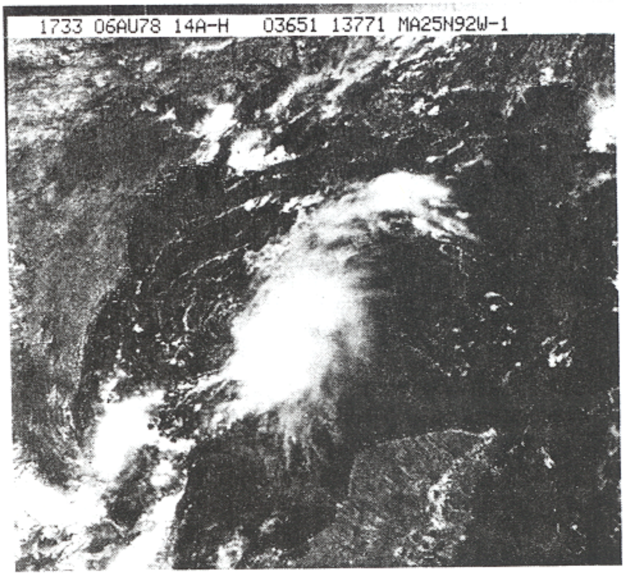

FIG. 5. Visible satellite picture of Bess at 1733 GMT 6 August 1978 from GOES 2 (½ n mi resolution).

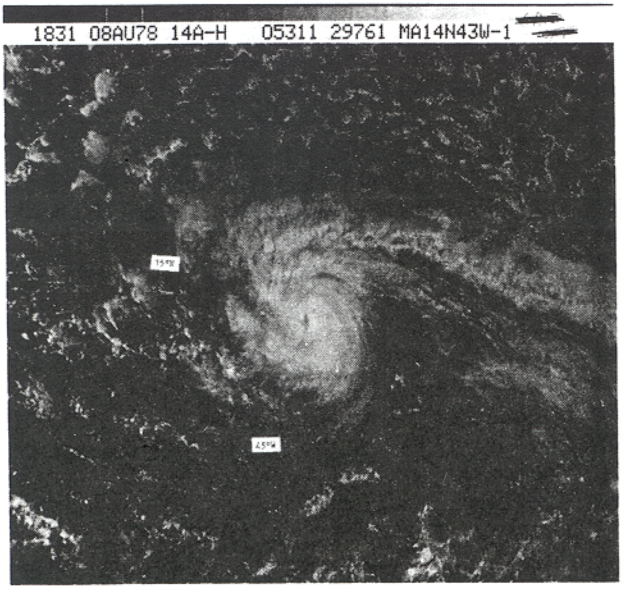

FIG. 6. Visible satellite picture of Cora at 1831 GMT 8 August 1978 from GOES 2 (½ n mi resolution).

near the point of landfall. Twenty-five kt winds were reported from Tampico and Tuxpan on 7 August as the center approached the coast. Satellite data indicated that rainfall associated with this storm decreased rapidly after landfall. There have been neither casualties nor significant damage attributed to Bess.

c. Hurricane Cora, 7–11 August

A weather disturbance moved off of the African coast on 4 August. It continued westward along the intertropical convergence zone for two days; then a circular cloud mass shifted northward and developed into a tropical depression. This depression intensified to tropical storm strength on 8 August at a location almost 1000 n mi west of the Azores.

The storm further intensified to a hurricane later the same day. This is based on satellite pictures that indicated the formation of an eye. One of these pictures is shown in Fig. 6. Cora was now moving on a course slightly south of due west at about 20 kt and this motion continued as the storm moved into the extreme southeast Caribbean.

On 9 August, Cora weakened while still east of the Lesser Antilles. The first reconnaissance flight into Cora took place on the afternoon of the 9th and 55 kt winds were the highest measured. The weakening trend continued and squalls to around 40 kt were reported on the islands of Barbados and St. Lucia as Cora crossed the Windward Islands on the 10th and 11th. On the 11th, Cora lost all evidence of circulation and was downgraded to a tropical wave. It continued into the southwest Caribbean and dissipated.

A point of interest is that Cora was identified as a tropical storm and then a hurricane solely on the basis of satellite pictures. Maximum wind speed and minimum pressure obtained from satellite intensity classification techniques were 80 kt and 980 mb during the period 0000–0600 GMT 9 August. Hurricanes Doris and Gladys in 1975 are the only other Atlantic storms to have been upgraded to hurricane status based on satellite pictures alone. (Operational reconnaissance procedures restrict the use of aircraft during times when a storm is far out at sea and does not pose an immediate threat to land.)

Rapid dissipation as Cora moved into the southeast Caribbean is not an unexpected event in this area. The entrainment of continental air from South America limits convective processes in the storm and strong tradewind easterlies produced by the geographic heat low disrupts the low-level circulation. Large-scale criteria were generally favorable otherwise for intensification, and yet the circulation completely disappeared within 24 h, which indicates the significance of continental influences.

There have been no reports of damage or casualties in connection with this storm.

d. Tropical Storm Debra, 26–29 August

The origins of Debra can be traced to an upper tropospheric low-pressure system which formed over southwest Florida on 25 August. For 36 h, this low drifted southwestward, reaching a position just north of the Yucatan Peninsula, simultaneously penetrating down into the lower troposphere.

Meanwhile, cloudiness, which appeared to be associated with a tropical wave, moved from the northwest Caribbean to the vicinity of the Yucatan Peninsula. This cloudiness interacted with the low-level vorticity center generated by the low from Florida, resulting in the formation of a tropical depression at 1200 GMT 26 August, at a position ~400 n mi south of New Orleans.

This depression first moved toward the west and then northward as the western extension of a high-pressure ridge weakened over Texas and Louisiana. Slow strengthening occurred and the system was upgraded to Tropical Storm Debra at 1800 GMT on the 28th on receipt of reconnaissance data of 40 kt surface winds. Debra was an immediate coastal threat and gale warnings were posted from Galveston, Texas, to Grand Isle, Louisiana, issued at 1800 GMT on the 28th.

The storm's maximum intensity (50 kt surface winds and 1000 mb central pressure) was reached at 0000 GMT 29 August, just before landfall. Fig. 7 shows Debra's appearance while approaching the coast and it is evident from the picture that this was not a particularly well-defined cloud system.

In addition, most of the high winds associated with the storm were found well east of the center. Automatic observation stations mounted on offshore platforms in the Gulf of Mexico measured sustained winds of 40–45 kt for several hours, as Debra passed 100–150 n mi to the west. Fig. 8 depicts low-level winds measured by a NOAA aircraft flying through the storm (note that the maximum winds are displaced some 1.5° of longitude from the circulation center).

After moving onshore, Debra accelerated north-northeastward across west central Louisiana and into Arkansas, where the residual low-pressure system combined with a frontal trough on 29 August. The resulting frontal wave was tracked across the Ohio Valley for the next three days.

Tides in connection with this storm ranged from 1 ft above normal at Corpus Christi to 2.2 ft at Galveston and 4–5 ft on the Louisiana coast from west of Atchafalaya Bay through Vermilion Bay.

The greatest total rainfall reported was 10.81 inches at Freshwater Bayou Lock, Louisiana. Amounts of 6 inches or more occurred in southwest Louisiana, southwest Mississippi, Arkansas, and later in southern Missouri and Illinois, as the remnants of Debra became a frontal wave. A summary of the meteorological storm data is given in Table 3.

Tornados occurred in Texas, Louisiana and Mississippi. One death was attributed to the Mississippi tornado and another death was reported to have occurred on an offshore oil rig. Total storm damage caused by Debra is considered to be minimal. An estimated 3000 or more persons were evacuated from low-lying coastal sections of Louisiana.

e. Hurricane Ella, 29 August–5 September

Ella's formation occurred within a decaying, quasi-stationary frontal zone over the central North Atlantic Ocean. On 28 August, within this previously baroclinic zone, satellite pictures suggested a cyclonic turning of low-cloud elements at a position ~500 n mi southeast of Bermuda. Ship and satellite data allowed the determination that a tropical depression had formed at this location by 0000 GMT 30 August.

The depression headed toward the west-northwest at a speed of 10–15 kt along the periphery of the Atlantic subtropical high-pressure ridge. A ship report of 47 kt wind just north of the center at 2000 GMT on the 30th indicated that tropical storm intensity had been reached several hours earlier.

Almost 24 h later, another ship reported a sea level pressure of 980 mb and 70 kt winds, which

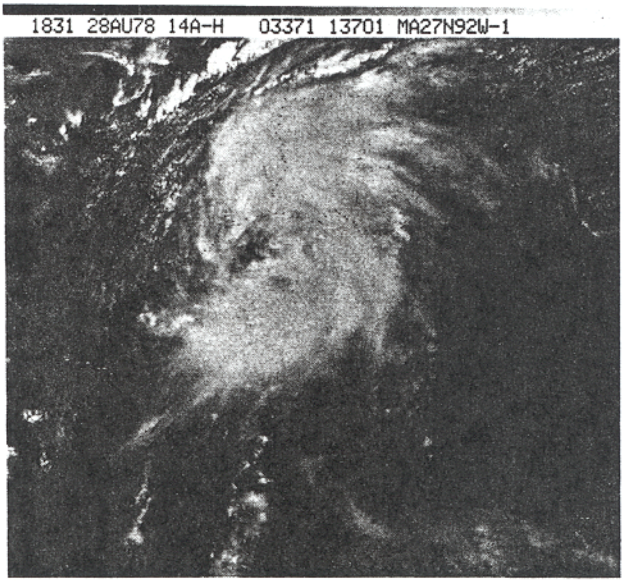

FIG. 7. Visible satellite picture of Debra at 1831 GMT 28 August 1978 from GOES 2 (½ n mi resolution).

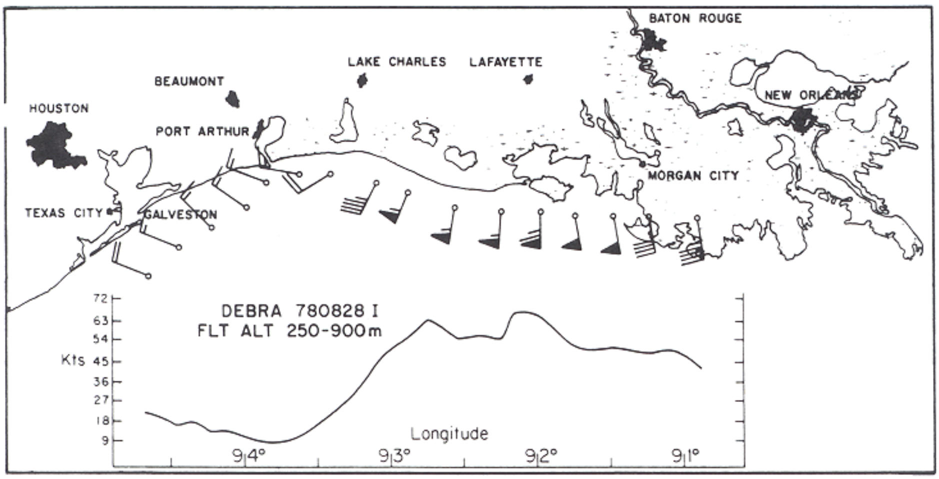

FIG. 8. Low-level winds along the Texas and Louisiana coast as Tropical Storm Debra made landfall. Winds measured by NOAA aircraft 43RF (Courtesy of R. Sheets.)

TABLE 3. Meteorological data of Tropical Storm Debra, 26–29 August 1978.

Station	Date	Pressure (inches)		Wind (mph)				Tide (ft)		Rainfall (inches)
		Minimum	Time*	Sustained	Time*	Peak gust	Time*	Height above MSL	Time*	
Louisiana										
Alexandria WSO	28	29.68	2300	31		45	2030			4.53
Alexandria Powerplant										5.03
Baton Rouge WSO	29	29.80	0353	21	0705	30	0700			3.61
Fort Pike on Rigolets	29							3.8	1345	
Freshwater Bayou Lock	29									10.81
Grand Chenier	28					S 66				
Lake Charles WSO	28	29.58	1953	26	1913	38	1925			5.88
Lake Pontchartrain north causeway	28							3.2	2203	
New Orlêans Moisant Airport	28			22	1313	SE 39	1924			
	29	29.82	0245							3.28
Mississippi										
Brookhaven	29									4.31
Bude	29									6.50
Clinton	29									4.66
Crystal Springs	29									3.47
Jackson WSFO	29	29.84	1000	SE 29	1002	SE 41	1000			0.95
Jackson (northeast)	29									2.90
Liberty	29									6.60
McComb	29									3.70
Texas										
Beaumont WSO	28	29.58	1900					1.8	1200	
	29			SW 23	0030	SW 32	0030			2.81
Galveston WSO	28	29.68	1745	N 30	1327	NE 38	1003	2.2	1145	0.20

* Central Standard Time.

agreed closely with an Air Force reconnaissance mission. Thus, Ella was upgraded to a hurricane at 1800 GMT 31 August, while located 500 n mi southeast of Cape Hatteras, North Carolina.

Ella continued toward the west northwest and gained strength. On 1 September a short-wave trough reached the U.S. East Coast and Ella began to decelerate and turn a little northward in response to pressure falls north of the hurricane. However, Ella was not picked up by this trough and by 2 September, high pressure over the northeast United States had bridged across the frontal trough, causing Ella's motion to decrease to a very slow northward drift (the storm speed was 4 kt or less for at least a 24 h period). Intensification had been continuous since the outset, but late on 1 September the storm began to weaken. After reaching a minimum of 959 mb at 2100 GMT on the 1st, the central pressure rose more than 20 mb during the following 24 h.

A satellite picture of Ella is shown in Fig. 9. At this time, the afternoon of 1 September, the storm was located about 300 n mi southeast of Cape Hatteras. With a central pressure of 960 mb, note that the eye is well-defined and the cloud structure appears to be of a rather classical circular shape.

On 3 September another trough moved from the Great Lakes eastward destroying the blocking ridge and causing large pressure falls. This time Ella responded and began accelerating toward the northeast, reaching a forward speed of 40 kt by the 5th. The storm passed very close to the southeast tip of Newfoundland and became extratropical as it combined with a frontal system over the North Atlantic.

Intensification began again on 3 September and continued until the 4th, when cold sea surface temperatures were encountered. During this period of strengthening, a minimum central pressure of 956 mb was reached along with 120 kt winds, as measured by reconnaissance aircraft on the 4th. Fig. 10 shows a satellite picture of the storm during the time of minimum central pressure—956 mb. It is seen that the eye structure is less well-defined than on the previous picture. Also, the cloud structure to the north indicates interaction with westerly flow, while Ella was well-removed from the westerlies three days earlier.

A graph of central pressure versus time is given in Fig. 11. The preceeding several paragraphs described the synoptic events connected with this

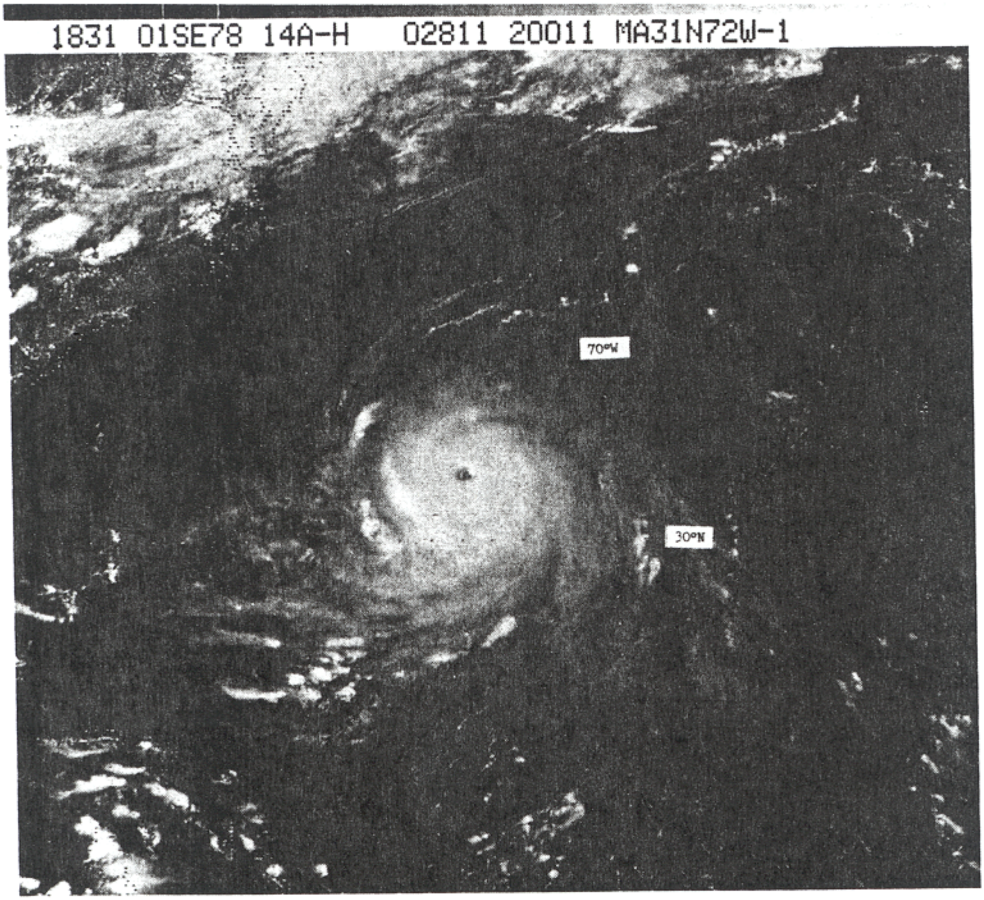

Fig. 9. Visible satellite picture of Ella at 1831 GMT 1 September 1978 from GOES 2 (½ n mi resolution).

figure. However, this pressure profile illustrates and emphasizes the large, natural variability that can occur in a mature hurricane.

A hurricane watch was issued for the Outer Banks of North Carolina on 1 September, the beginning of the Labor Day weekend. This was done as a course of least regret as Ella was already within 400 n mi of the Outer Banks and forecast to move even closer prior to recurvature. As it happened, the only storm effect on the Outer Banks consisted of beach erosion. The media reported that the tourist industry in this area suffered a "major disappointment" as a result of publicity in connection with the hurricane threat.

f. Hurricane Flossie, 3–16 September

The track of Flossie was confined to the open North Atlantic Ocean and this storm was never a threat to any land areas.

A strong wave passed off the African coast on 31 August with Dakar, Senegal, measuring the rather low surface pressure of 1009 mb. This wave strengthened into a depression by 0000 GMT 4 September, midway across the Atlantic. This information is based on satellite picture interpretation as well as a 1200 GMT ship report of 40 kt winds, which also resulted in the naming of Flossie several hours later.

Flossie moved at 20 kt toward the northwest, then west, for several days, with little change in strength. On 7 September the subtropical high-pressure ridge, to Flossie's north, weakened in response to the development of a strong extratropical low at higher latitudes. Recurvature commenced and the storm weakened back to a depression, presumably as a result of interaction with the circulation of the extratropical system to the north. The surface circulation center was almost completely obliterated by falling pressures north and west of Flossie.

Now moving northeastward, reintensification occurred and tropical storm strength was regained on the 10th. Far out in the Atlantic and no threat to land, Flossie stalled on the 12th. During this time, an eye was seen on satellite pictures, and the storm was upgraded to a hurricane at 0600 GMT on 12 September.

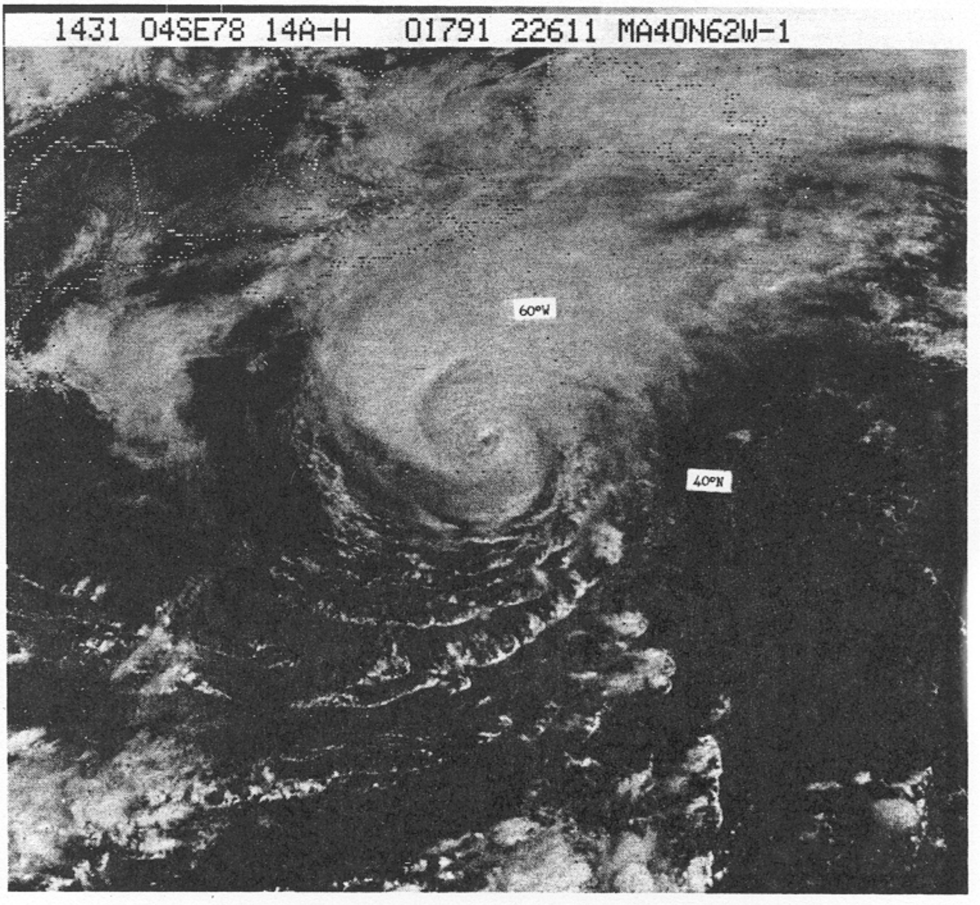

FIG. 10. Visible satellite picture of Ella at 1431 GMT 4 September 1978 from GOES 2 (½ n mi resolution).

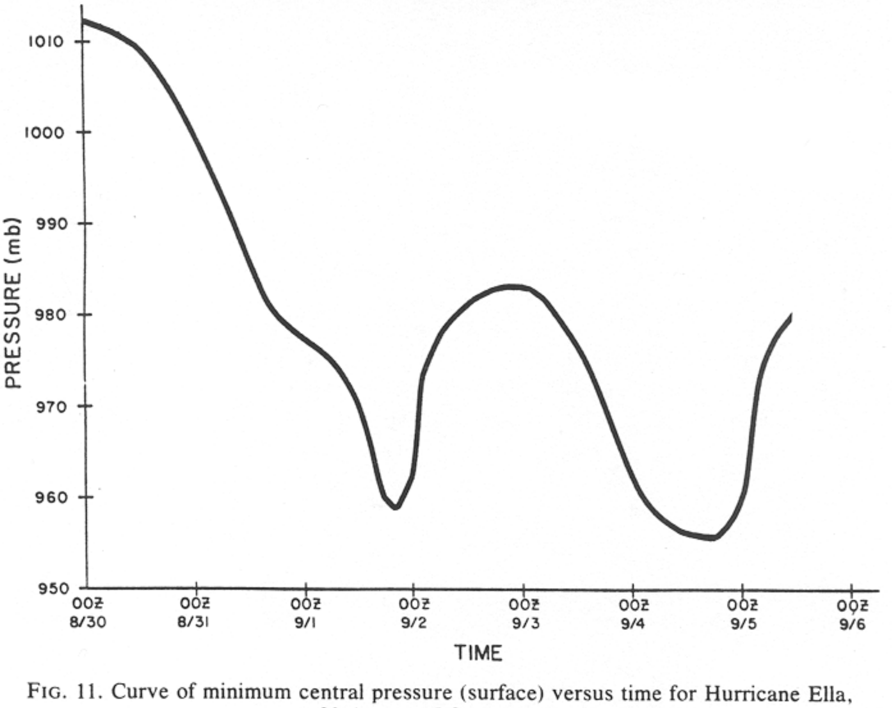

FIG. 11. Curve of minimum central pressure (surface) versus time for Hurricane Ella, 30 August–5 September.

Maximum winds of 85 kt and 976 mb minimum pressure are based on satellite data and were reached on the 13th. Fig. 12 shows a satellite picture of Flossie within a few hours of maximum intensity. Finally, moving off toward the northeast, Flossie became extratropical 700 n mi north of the Azores late on the 15th.

g. Hurricane Greta, 13–20 September

1) Meteorological history

The first signs of development were an increase of convection and cloud organization in connection with a tropical wave which departed Africa on 7 September. This occurred on the 10th, halfway between Africa and the Windward Islands. This wave immediately followed the one from which Flossie developed, resulting in hurricanes being generated from two tropical waves in a row.

Barbados reported winds gusting to 45 kt as the wave moved into the Caribbean on the 13th. Although the southeastern Caribbean is not a climatologically favorable location for tropical development, a depression formed on the 13th, 75 n mi west northwest of Port-of-Spain, Trinidad. Greta was named at 1200 GMT 14 September while located just north of the Netherlands Antilles. These islands experienced heavy showers, but strong winds were confined to the north of the storm center.

Hurricane intensity was reached at 1200 GMT 16 September at a location due south of Jamaica as a westnorthwest movement continued across the Caribbean. The central pressure reached its minimum of 947 mb (115 kt maximum winds) early on the 18th as reported by an Air Force reconnaissance plane.

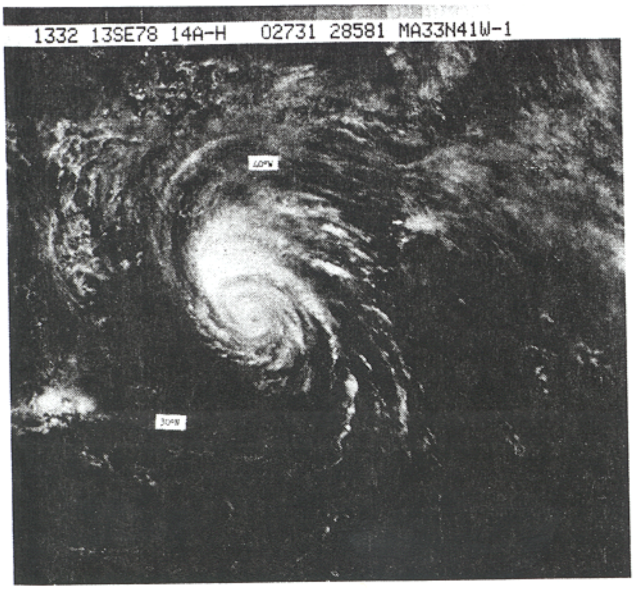

Fig. 12. Visible satellite picture of Flossie at 1332 GMT 13 September 1978 from GOES 2 (½ n mi resolution).

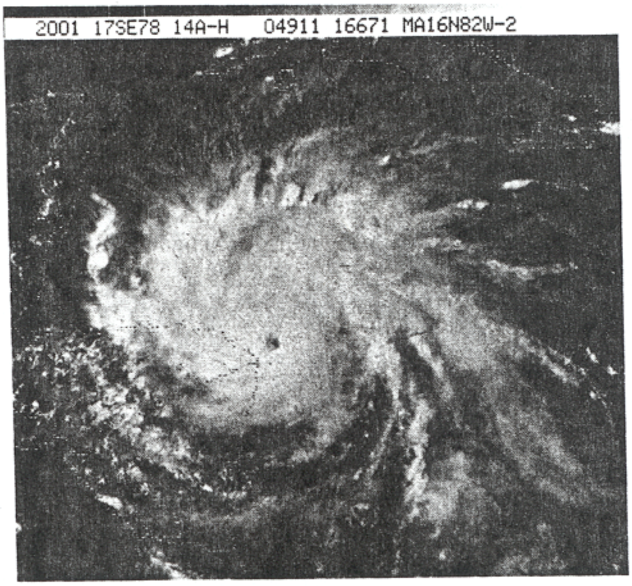

Fig. 13. Visible satellite picture of Greta at 2001 GMT 17 September 1978 from GOES 2 (½ n mi resolution).

The eyewall of Greta crossed over the extreme northeast coast of Honduras during this time of maximum intensity. Puerto Lempira, Honduras, reported winds of 70 kt gusting to 100 kt from the north-northwest at 0000 GMT 18 September, and 3 h later reported 50 kt gusting to 70 kt from the southwest. Fig. 13 shows Greta, with a well-defined eye, several hours prior to striking the Honduras coast, and about 10 h before time of maximum intensity.

Satellite picture time-lapse movie loops show that Greta's eye appeared to literally "bounce" off of the coastline, and the remainder of Honduras' north coast was not directly affected by the dangerous eyewall.

The hurricane weakened as it continued westward, landfalling near Stann Creek, Belize, at 0000 GMT 19 September. Central pressure at landfall was estimated at 964 mb. Traveling inland, Greta decreased to below storm strength over northwest Guatemala by 1200 GMT 19 September. A high-pressure ridge oriented northeast/southwest across the Gulf of Mexico steered the depression into the Pacific Ocean, where it quickly regenerated into Tropical Storm Olivia, and into a minimal hurricane 36 h later. Olivia looped to the south of Tehauntepec on the Mexican coast, and moved back inland at 1800 GMT on the 22nd. Olivia turned northwest and weakened, but still produced 35 kt winds at Vera Cruz on the 23rd.

2) Damage

One death was reported from Honduras and four from Belize. An unofficial damage estimate for

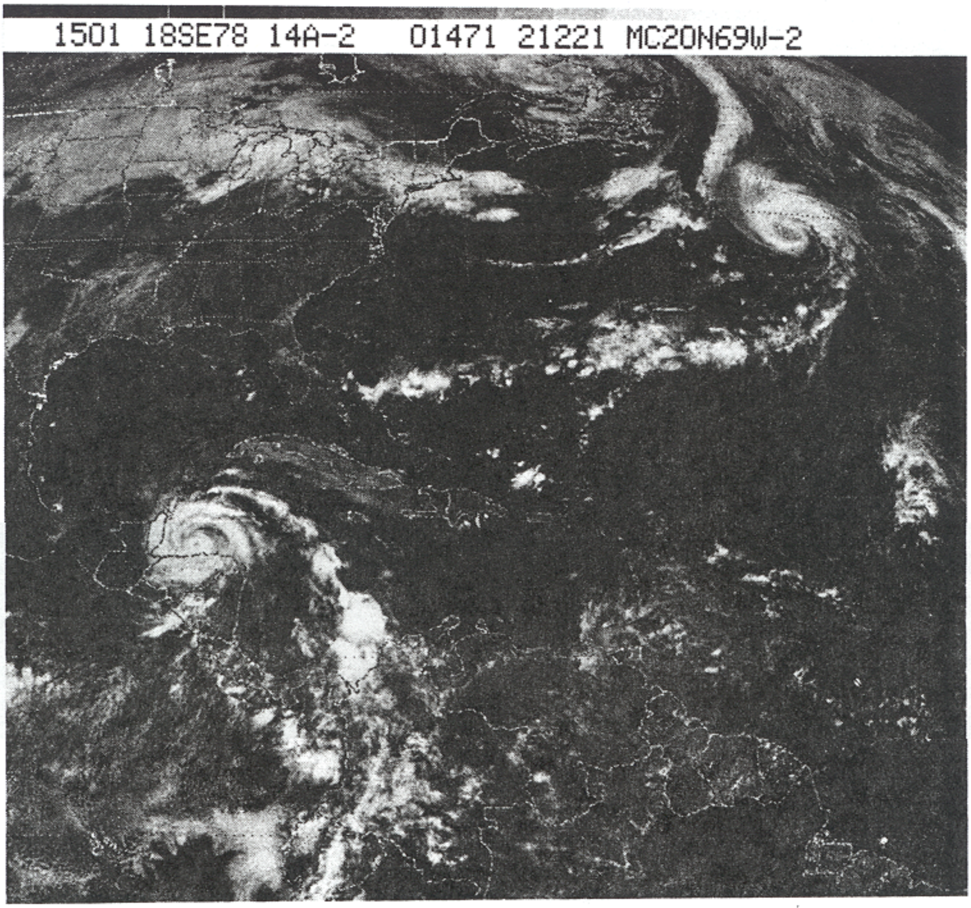

FIG. 14. Visible satellite picture of Hope at 1501 GMT 18 September 1978 from GOES 2 (2 n mi resolution). Hope is located in the North Atlantic in the upper-right portion of the photograph. Greta can also be seen approaching Belize.

Belize is $25 million, mainly from crops and utilities damages. Winds to 80 kt with tides up to 7 ft above mean sea level were reported from Stann Creek, Belize. Winds and tides were less at Belize City to the north.

While there were locally heavy rains over portions of Central America, Greta did not produce the devastating river floods that occurred with Hurricane Fifi, four years earlier (Hope, 1975). Greta and Fifi had similar tracks; but while Greta was a more intense storm, Fifi was much wetter and was responsible for thousands of deaths on that basis.

h. Tropical Storm Hope, 11–21 September

A mid-tropospheric low-pressure system contributed to the formation of a subtropical depression just offshore of the northeast coast of Florida on 11 September. The depression moved east northeastward for a few days, strengthening to a subtropical storm on the 14th, while passing a short distance north of Bermuda. Bermuda was not affected significantly as there was a broad area of light winds near the storm center.

By 17 September, satellite pictures indicated that convective cloudiness was becoming more concentrated over an area closer to the center and Hope was designated as a tropical storm on that day. Hope accelerated toward the northeast and reached maximum strength on the 19th. Fig. 14 shows a picture of Hope on the 18th at a time when storm intensity was only slightly less than maximum. The storm became extratropical to the northwest of the British Isles on 21 September.

There were no reconnaissance flights during the time that Hope was classified as a tropical system. Based on satellite interpretation, highest winds were estimated to be 55 kt. The ship S.S. *Banglar Mann* passed through the center on the morning of the 19th and measured a pressure of 987 mb. Hope did not affect land and there have been no reports of marine-related incidents.

i. Tropical Storm Irma, 2–5 October

Irma developed from a low-pressure system of subtropical origin which formed 500 n mi south of the Azores in the eastern North Atlantic on 2

October. Convection gradually increased as the low drifted northward. By 4 October, the system had taken on the appearance of a tropical storm, as seen on satellite photographs, and upper level anticyclonic flow at the cirrus level was evident from satellite time-lapse movies. Fig. 15 shows a photo of Irma on the 4th.

Tropical storm advisories were initiated on the afternoon of the 4th, indicating a threat to the Azores. On 5 October, Irma passed midway between the westernmost islands of Corvo and Flores and the group of larger islands of the central Azores. However, the only gale-force winds reported were from a few ships well to the east of the storm center in an area of strong pressure gradient between Irma and a high farther northeast.

The storm lost its identity on the 5th, as it was overtaken and absorbed by a strong frontal system to the north of the Azores.

Satellite pictures were the primary data source concerning this system—only a few island reports were received. There have been no reports of damage or casualties.

j. Tropical Storm Juliet, 7–11 October

A weak tropical wave moved off of the African coast on 30 September. It traveled west-northwestward, reaching a position 600 n mi east of the Leeward Islands on 6 October. By this time, satellite pictures indicated that the cloud field had become notably more concentrated with weak evidence of anticyclonic turning at the cirrus cloud level. Midday on the 7th, low-level cloud lines and a few ship reports indicated that a closed circulation was forming at the surface about 600 n mi east of San Juan, Puerto Rico. The system was classified as a tropical depression at 1800 GMT.

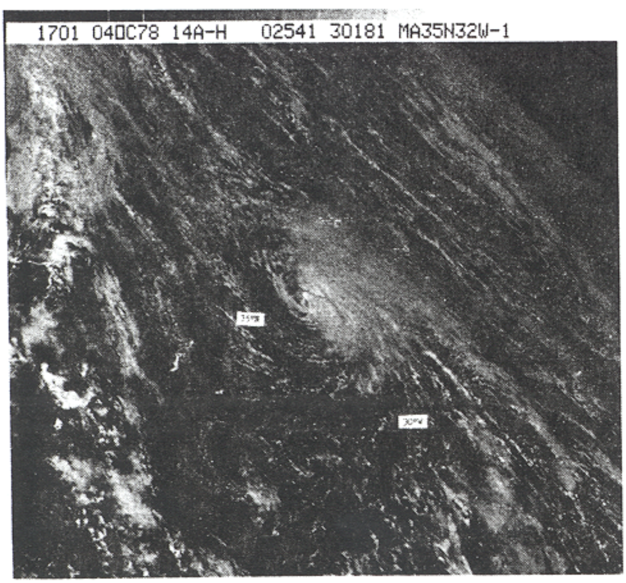

Fig. 15. Visible satellite picture of Irma at 1701 GMT 4 October 1978 from GOES 2 (½ n mi resolution).

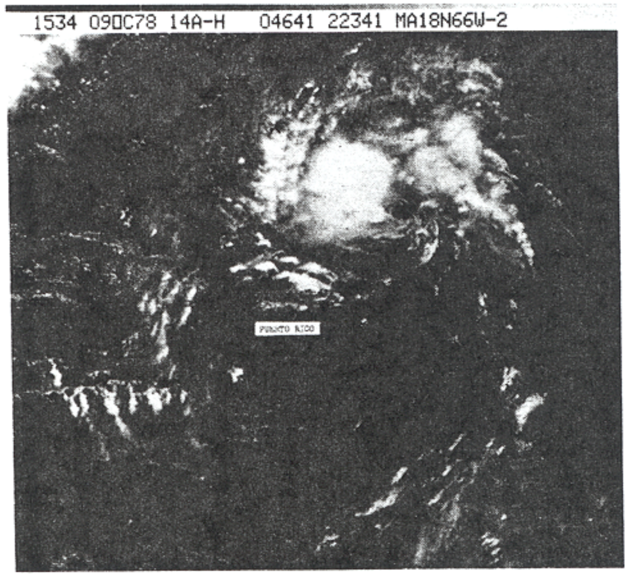

Fig. 16. Visible satellite picture of Juliet at 1534 GMT 9 October 1978 from GOES 2 (½ n mi resolution).

The depression was named Tropical Storm Juliet on the 9th. Post analysis indicates that storm strength was reached at 1200 GMT on the 8th at a position 400 n mi east northeast of San Juan.

Juliet gradually recurved during the next several days in response to a short-wave trough moving eastward from the southeastern United States. A gradual acceleration to a 20 kt forward speed accompanied this recurvature, as strong westerlies aloft were encountered at more northern latitudes. The storm passed 150 n mi north of San Juan on 9 October and was last located 300 n mi southwest of Bermuda at 1200 GMT on the 11th, before becoming absorbed by a developing extratropical low-pressure system.

Maximum sustained winds of 45 kt and minimum sea level pressure of 1006 mb were reached on the 9th and this intensity was maintained for most of Juliet's existence. A satellite view of the storm at 1534 GMT on the 9th is shown in Fig. 16.

Well-defined cloud characteristics—such as central dense overcast and low-level banding or strong outflow pattern—were never in evidence. Also the minimum pressure of 1006 mb does not ordinarily support tropical storm intensity for any length of time. However, surface pressure anomalies were well above normal over the western North Atlantic and this provided the necessary pressure gradient for sustained gale-force winds.

Satellite pictures showed that an active convective cloud mass associated with Juliet's remnants moved across Bermuda late on the 11th, producing over 3 inches of rain during a 12 h period.

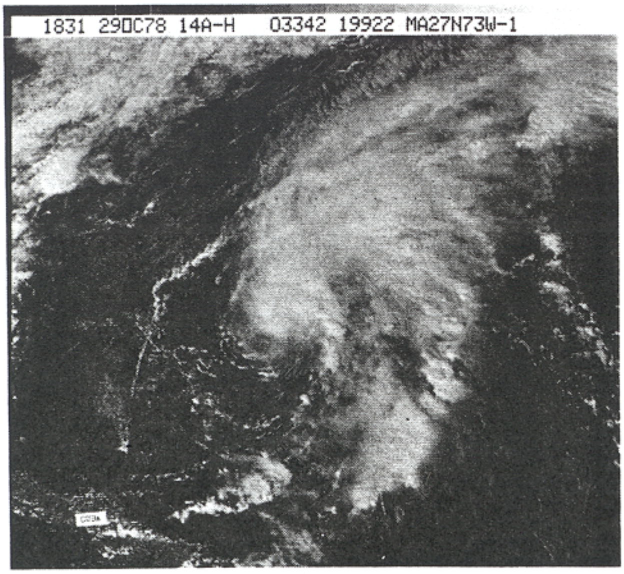

FIG. 17. Visible satellite picture of Kendra at 1831 GMT 29 October 1978 from GOES 2 (½ n mi resolution).

By this time, however, there was no longer any evidence of a surface circulation near the area of the storm remnants.

No death or damage reports have been received in connection with Juliet.

k. Hurricane Kendra, 28 October–3 November

Disturbed weather was observed over the eastern Caribbean for several days during late October. Some locations in Puerto Rico measured over 18 inches of rain during the period 22–27 October. A tropical wave which left the African coast on 15 October reached the eastern Caribbean on the 21st and appears to have been a factor in initiating this persistent weather disturbance.

Concurrent with the activity described above, cloudiness associated with an old frontal zone slipped southward to merge with the rain-producing system in the general vicinity of Puerto Rico. Eventually, the disturbed weather shifted northwestward and satellite pictures showed a very concentrated convective area to the north of Hispaniola during the night of 27–28 October. During 28 October, subsequent pictures revealed increasing organization. A depression developed just east of the Bahamas that afternoon.

Kendra was named as a tropical storm at 0000 GMT on the 29th. This is based on satellite imagery as well as a ship report of 999 mb and winds to 60–70 kt. Hurricane status was reached on the afternoon of the 29th, when a reconnaissance plane estimated 70 kt surface winds.

There was little change in strength during the next 24 h as the hurricane moved north-northeastward. Kendra is shown in Fig. 17 while located just east of the northern Bahamas. But by late on the 30th, Kendra encountered strong upper level westerlies, which separated the dense convection from the low-level circulation. Weakening ensued and Kendra was downgraded to a tropical storm at 0000 GMT 31 October. A few hours later, surface winds had decreased to below gale force, and there was little tropical cloud structure in evidence.

However, a 1008 mb surface low persisted and accelerated northeastward. This low deepened on the next day, under the influence of a strong upper trough moving off of the U.S. East Coast. The system was finally absorbed by another extratropical low over the northeast North Atlantic.

Gale warnings were required along the North Carolina coast on the 30th and 31st, as a result of the interaction between Kendra and an intense polar anticyclone over the northeast United States.

Significant damage from this storm was restricted to the predepression stage, which produced the heavy rains over Puerto Rico, 12 inches in the Ponce area and 18 inches in the Humacao area of southern Puerto Rico. There was one death and about 1000 families sheltered. Newspaper reports listed damages at about $6 million, all water-related.

3. Subtropical storm of 18–22 January

There was one system identified as a subtropical storm during 1978. It occured in January and historical records (Neumann *et al.*, 1978) indicate that this is the first time that a tropical or subtropical cyclone of at least storm intensity formed in this month (a

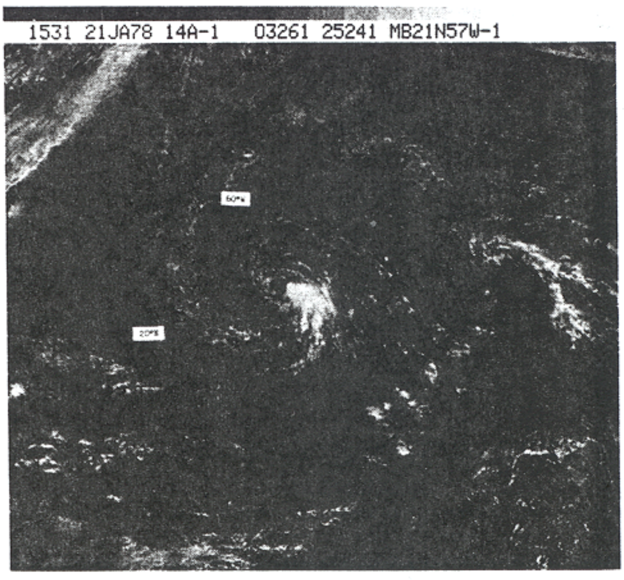

FIG. 18. Visible satellite picture of unnamed subtropical storm at 1531 GMT 21 January 1978 from GOES 2 (1 n mi resolution).

hurricane in the Leeward Islands on 2 January 1955 reached storm strength on 30 December 1954).

The storm originated 1500 n mi east northeast of Puerto Rico on 18 January. The initiating mechanism was an upper tropospheric trough in the westerlies. The presence of this trough resulted in the development of a surface low to the south of the surface subtropical high pressure ridge that extends across the Atlantic. A strong pressure gradient to its north caused the surface low to acquire gale-force winds by 1200 GMT 19 January. The new subtropical storm moved toward the west-northwest, turning southwestward late on the 20th. This storm track is indicated in Fig. 1 as system number 1.

Maximum winds of 40 kt and a minimum sea-level pressure of 1002 mb were reached on the 20th and 21st. Fig. 18 shows a visible satellite photograph of the storm on the 21st. Weakening began several hours after this photograph was taken and winds dropped below gale force by 1200 GMT 22 January. The center opened into a trough later on the same day.

The following tropical characteristics associated with this storm are in evidence in Fig. 18:

1) There is significant convection not too far removed from the circulation center.

2) The storm is isolated from any weather-producing systems in the westerlies. Features which are not tropical in nature include (i) an initial energy source which was baroclinic, (ii) sea surface temperature values of 24°C or lower, and (iii) maximum winds reported by ships and reconnaissance which were 50–100 n mi from the storm center.

It is of interest to note that this rare storm occurred only several days prior to two extreme weather events—a late January Ohio Valley storm and a northeast coastal storm two weeks later. Both events were associated with a deep mean trough located over the eastern United States, and the downstream large-amplitude ridge over the western North Atlantic created favorable conditions for subtropical storm development.

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