Atlantic Hurricane Season of 1977

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ABSTRACT

A summary of the 1977 Atlantic hurricane season is presented along with detailed accounts of individual storms.

This season was a rather inactive one, with fewer storms than normal. Anita was an intense hurricane in the Gulf of Mexico, but made landfall along a sparsely populated section of the Mexican coast. Babe was the only named storm to cross the United States coastline this year.

1. General summary

The 1977 Atlantic hurricane season can be characterized as an inactive one. There were six named tropical cyclones, of which five reached hurricane force. Fig. 1 and Table 1 contain the tracks and summaries for these storms.

While six named storms is below the long-term average of eight,[1] there are other indicators which clearly show the anomalous nature of the 1977 hurricane season. Specifically, there were nine hurricane days in 1977, which compare to the preceding 20-year average of 29 days. (One hurricane day is counted for each day that a hurricane is ongoing; two days are counted if two hurricanes exist on the same day.)

The first storm was named on 29 August, an extremely late start. Fig. 2 shows the cumulative frequency distributions of the beginning and ending dates of the Atlantic hurricane season since 1886. It is seen that fewer than 10% of the seasons begin as late as 29 August. Closely related is the length of time between beginning and ending dates, which was only 51 days in 1977. The average for the past 10 years is 110 days.

Examination of the storm tracks in Fig. 1 shows that all storm genesis occurred west of longitude 60°W. This has happened only one other time (1972) during the past 30 years. This westward shift is reflected in the number of hurricane days, since there was no opportunity for a storm to travel across the tropical Atlantic.

Variation in hurricane activity from season to season has been a subject of investigation for many years. A basic premise involved here is that these fluctuations are causally related to variations in general circulation features (see e.g., Ballenzweig, 1958; Namias, 1955). The following discussion is offered in this view.

Fig. 3 shows the average geopotential height field at 700 mb for September 1977 and Fig. 4 contains the long-term normals for this height field for the month of September. Taubensee (1977), in his discussion of the weather and circulation of September 1977, mentioned the weaker than normal subtropical high-pressure ridge across the north Atlantic and its relationship to a long-wave trough position to the east of North America. Fig. 3 clearly shows the weakness of the subtropical ridge as compared to normal (Fig. 4). This results in a decrease of approximately 50% in the normal north-south height gradient over the central North Atlantic between 5 and 25°N. Hence, the easterlies at 700 mb in this region are only half of their normal value of $\sim$20 kt. Further, the north-south shear of the easterly zonal wind was also decreased from its normal value in this area. That this is the case is supported by noting that the 3150 height contour remains near its normal position along 5°N while the ridge weakened further north.

Norquist *et al.* (1977) present evidence to support the theory that a significant portion of the energy needed to maintain African waves in the extreme eastern Atlantic is made available through the north-south shear of the easterlies. However, it is not known to what extent this concept is valid when applied further west across the Atlantic.

Shapiro (1977) also relates the development potential of African waves to the strength of horizontal wind shear in the Atlantic trade wind zone. In fact, operational testing of his criterion this season consistently resulted in forecasts of little likelihood of storm genesis over the central North Atlantic.

An examination of geopotential height anomalies at 1000, 700 and 500 mb (not shown) for September 1977 shows that the negative anomalies increase with height in the region of the subtropical ridge. This results in a westerly shear (west wind increasing with height or east wind decreasing with height) between 1000 and 500 mb. Landers (1963) concluded that a net westerly shear is unfavorable for wave intensification.

In connection with this season's late start, the following is noted. Neither of the parameters (low sea

[1] This average, computed over the period 1900–76, is 8.0 named storms, of which 4.7 reached hurricane force.

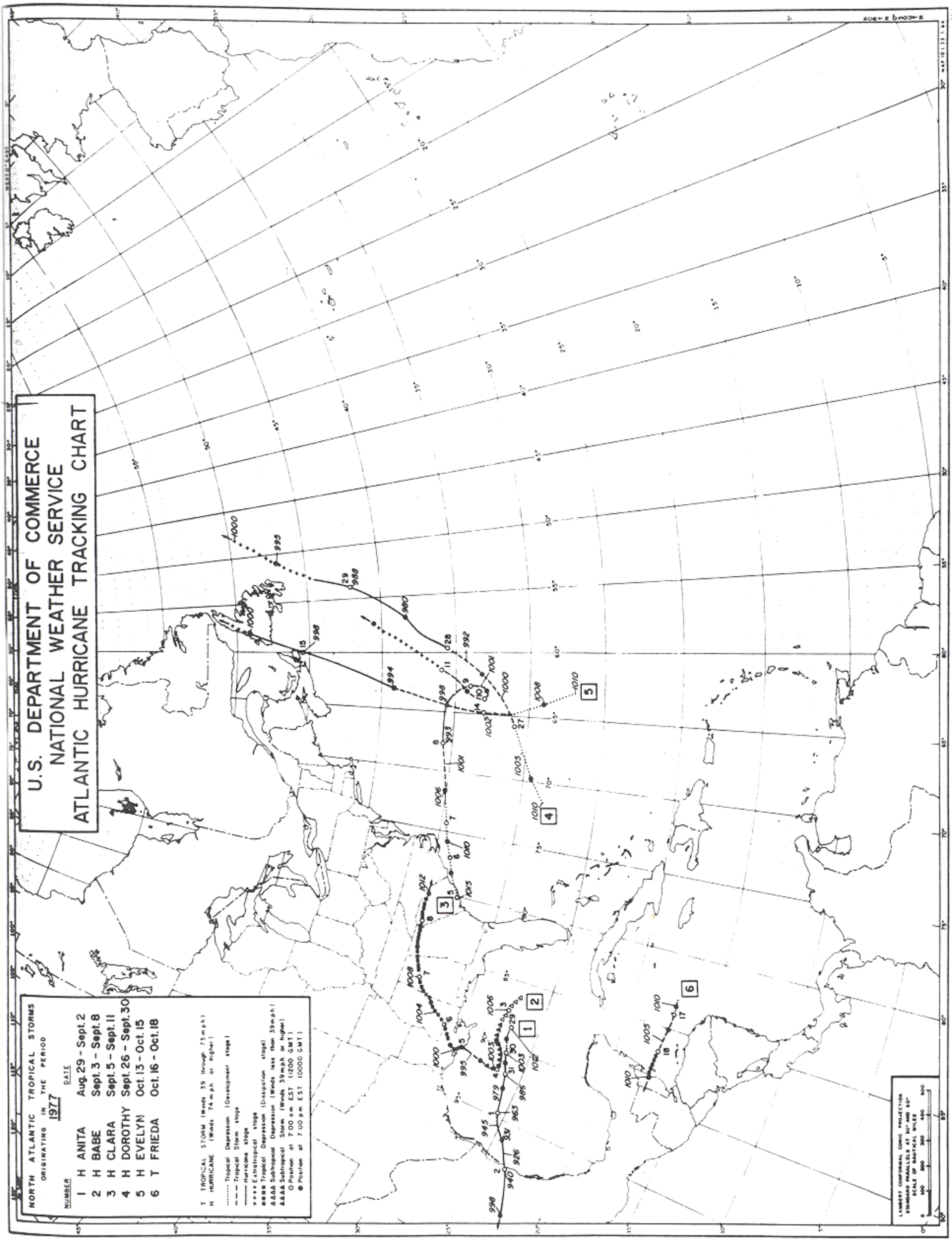

FIG. 1. Tracks of North Atlantic tropical cyclones, 1977.

TABLE 1. Summary of North Atlantic tropical cyclone statistics, 1977.

No.	Name	Class	Dates	Maximum sustained winds (kt)	Lowest pressure (mb)	U.S. damage ($ million)	Deaths
1	Anita	H	29 Aug–2 Sep	150	926	minor	Mexico, 10
2	Babe	H	3–8 Sep	65	995	10	
3	Clara	H	5–11 Sep	65	993		
4	Dorothy	H	26–30 Sep	75	980		
5	Evelyn	H	13–15 Oct	70	994		
6	Frieda	T	16–18 Oct	50	1005		

surface temperatures and high vertical wind shear), usually indicative of suppressed storm activity, were significantly below or above, respectively, their prohibiting threshold values over the tropical waters.

Only one tropical storm (Babe) made landfall in the United States this season. This is less than the average for this century of 3.2 tropical cyclone landfalls, including 1.8 hurricanes. Babe caused damage estimated at $10 million, but no loss of life.

Hurricane Anita was the fourth most intense storm of record in the Gulf of Mexico. The central pressure reached 926 mb and maximum winds were 150 kt. Anita made landfall along a sparsely populated region of the Mexican coast.

2. Individual named storms

a. *Hurricane Anita, 29 August–2 September*

1) PREDEPRESSION

The origins of Anita have been traced to a tropical wave that moved off the African coast on 16 August 1977. This wave traveled westward across the Atlantic similar to many other disturbances seen at this time of year. The wave then headed west-northwestward as it neared the Caribbean. Weather associated with this system spread across the Bahamas on 25 and 26 August, and over Florida and western Cuba on the 27th.

On 23 August, just northeast of the Windward Islands, the wave moved under a 200 mb cold low, and the associated cloudiness reflected this upper level cyclonic circulation pattern. The cloud system now continued northwestward while the upper low moved west, and by 27 August most of the associated weather was over Florida and the northern Bahamas.

Disturbed weather persisted for several days, producing several inches of rain. On 28 August the system shifted into the eastern Gulf of Mexico where the upper level flow pattern was mainly anticyclonic.

2) DEPRESSION TO HURRICANE

A tropical depression formed in the east central Gulf of Mexico on 29 August. Its center was about 200 n mi south-southwest of New Orleans. This system, steadily intensifying, moved west-southwestward for the next four days, making landfall on the morning of 2 September along the upper Mexican coast. Anita's forward speed was about 4 kt when south of New Orleans and gradually accelerated to 10 kt just prior to landfall.

Anita attained tropical storm strength near 0600 GMT 30 August or about 18 h after becoming a tropical

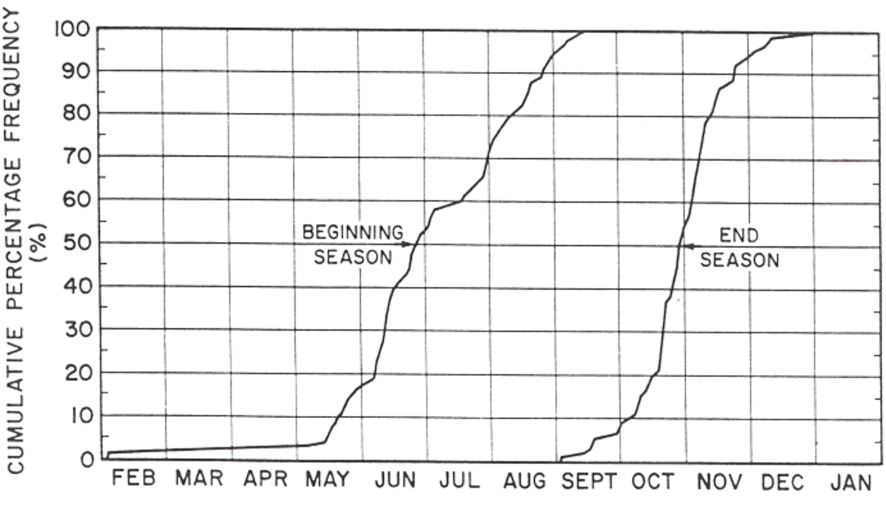

FIG. 2. Cumulative percentage frequency distribution of beginning and ending dates of Atlantic hurricane seasons (courtesy of C. J. Neumann).

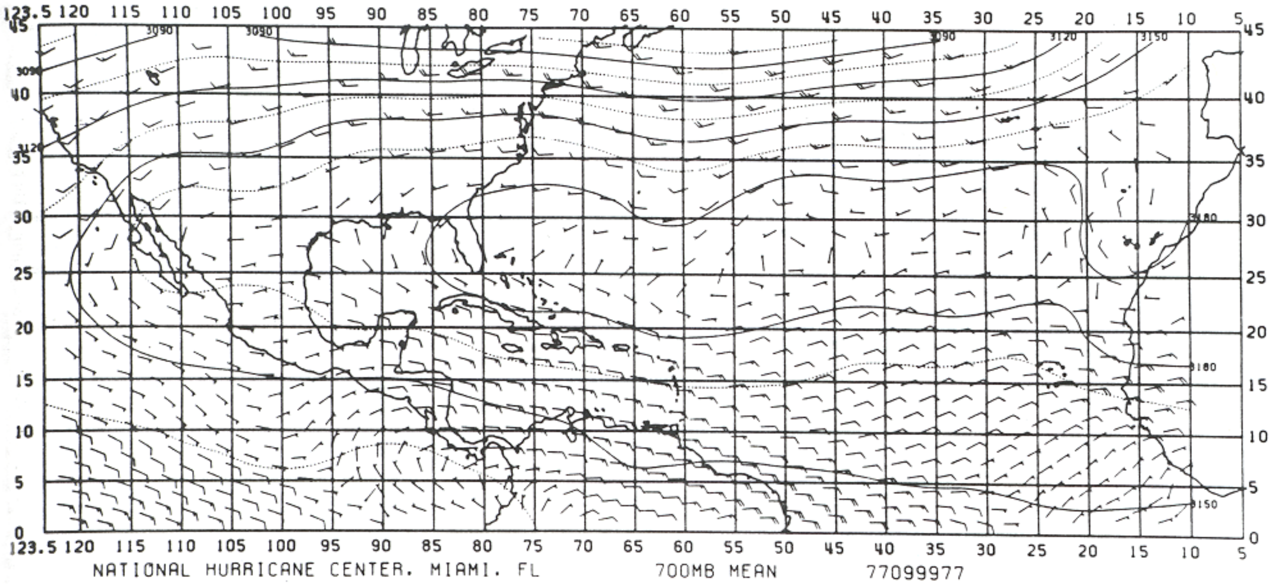

FIG. 3. 700 mb average geopotential heights (m) and winds (kt) for September 1977.

depression. Twelve hours later, hurricane force was reached. Strengthening continued until a minimum pressure of 926 mb was measured just prior to landfall. Maximum surface winds are estimated to have reached 150 kt. Fig. 5 shows a profile of pressure versus time taken from a NOAA aircraft near the time of maximum strength.

On 29 and 30 August, Anita's central pressure dropped at the rate of 0.5 mb h^{-1} and this rate increased to 2.0 mb h^{-1} for the following two days. The storm center moved very close to three data buoys in the Gulf of Mexico. Wind and pressure profiles versus time are shown from data buoy EB-71 (26.0°N, 93.5°W) in Fig. 6. The center passed within 20 n mi of EB-71 early on 1 September.

3) WARNINGS

Anita's course was toward the west-southwest during the four-day period that it traversed the Gulf of Mexico. However, there were minor oscillations in the track that introduced uncertainty in the forecast motion of this storm. These oscillations do not appear clearly in the track (Fig. 1) because of the small scale sizes involved. Lawrence and Mayfield (1977) discuss problems associated with this type of oscillation.

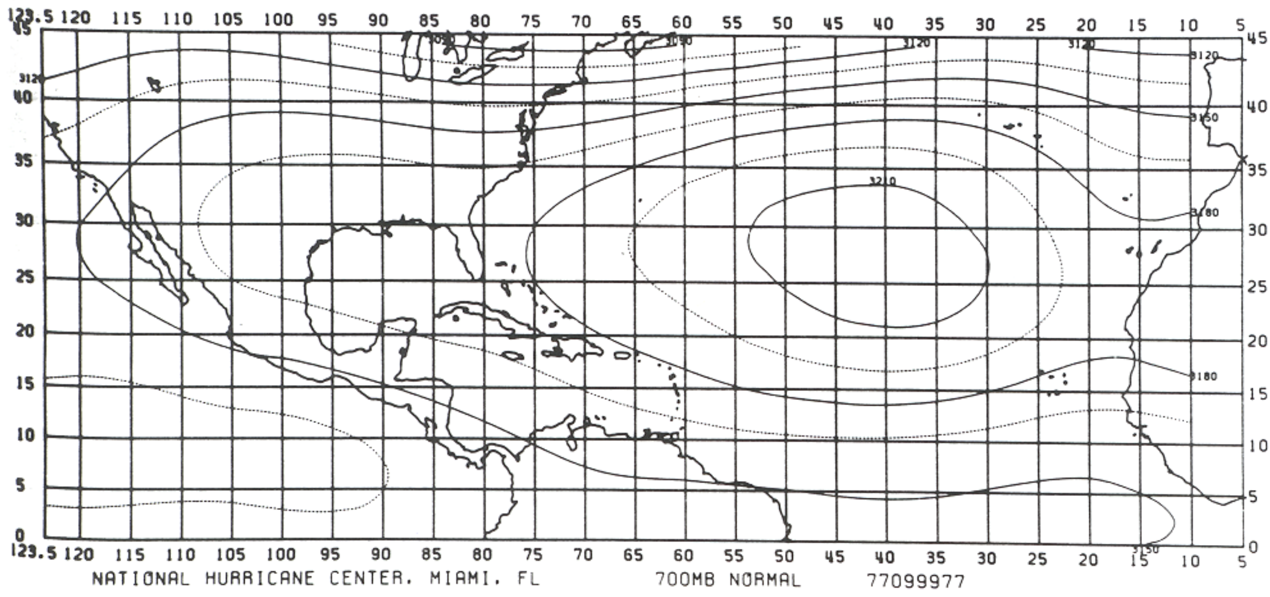

FIG. 4. 700 mb normal geopotential heights (m) for the month of September.

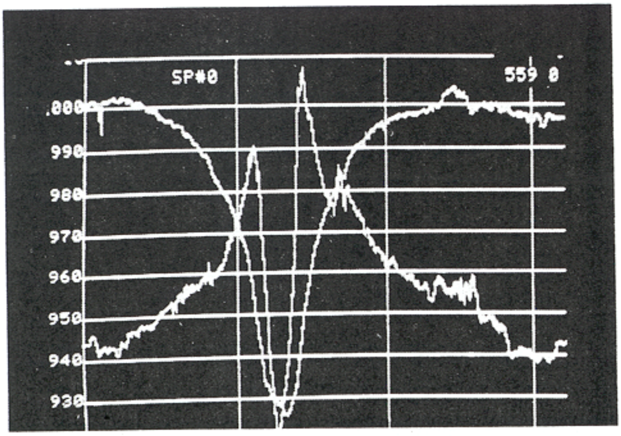

FIG. 5. Sea level pressure and wind speed profiles vs time for Hurricane Anita, measured by NOAA aircraft (courtesy of R. Sheets). Time from 0059–0654 GMT 2 September; x axis, 15 min intervals (~65 n mi); y axis, mb

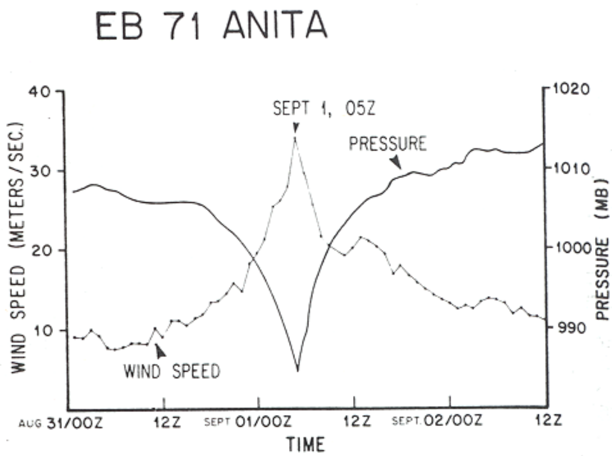

FIG. 6. Pressure and wind speed observations during Anita passage from data buoy EB-71 (26.0°N, 93.5°W). Wind speeds are averaged over an 8.5 min period.

A hurricane watch was placed along the Texas and southwest Louisiana coast at 2200 GMT 30 August. A hurricane warning was issued at 1000 GMT 1 September from just south of Corpus Christi, Tex., to Brownsville, Tex. The United States does not issue hurricane warnings for Mexico, but the Mexican government was notified of the potential danger.

Soon after warnings were issued, Anita made a small shift in direction from a heading of 260° to 235°, and it was at this time apparent that the main threat from this dangerous storm would be to the northeast Mexican coast.

Landfall occurred at 1100 GMT 2 September about 80 n mi north of Tampico (or 145 n mi south of Brownsville). The nearest population center in the path of Anita was the inland village of Soto La Marina, 165 n

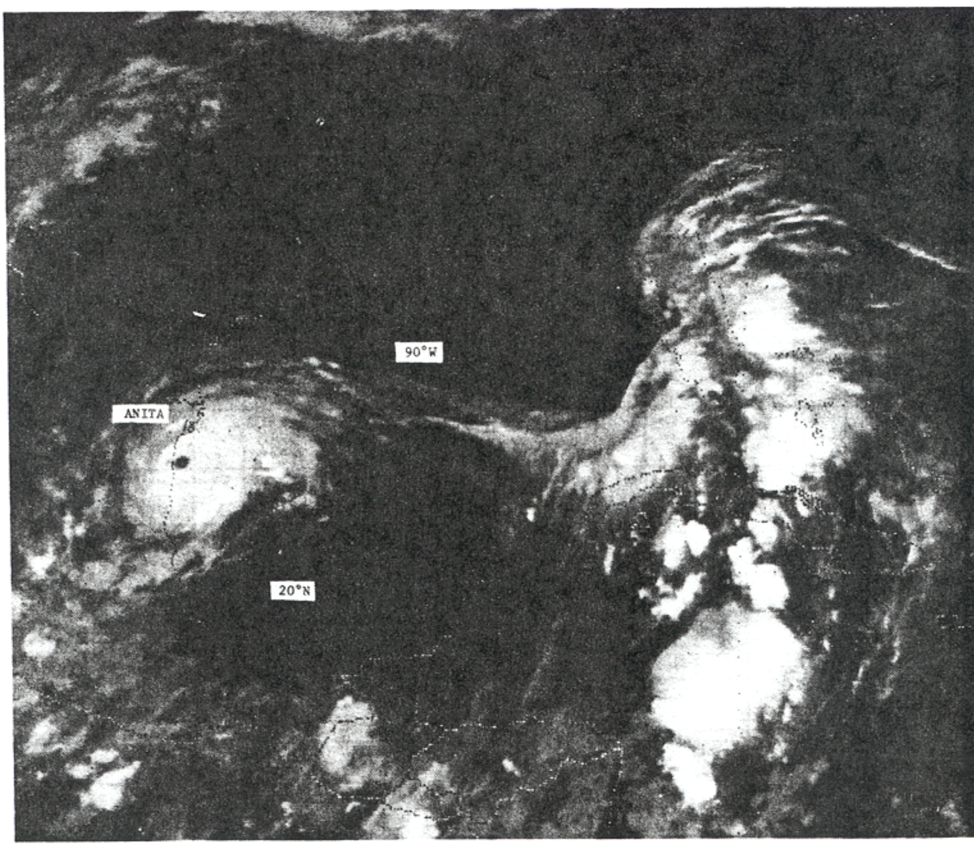

FIG. 7. Infrared satellite picture of Anita at 0631 GMT 2 September 1977 from GOES-2 (1 n mi resolution).

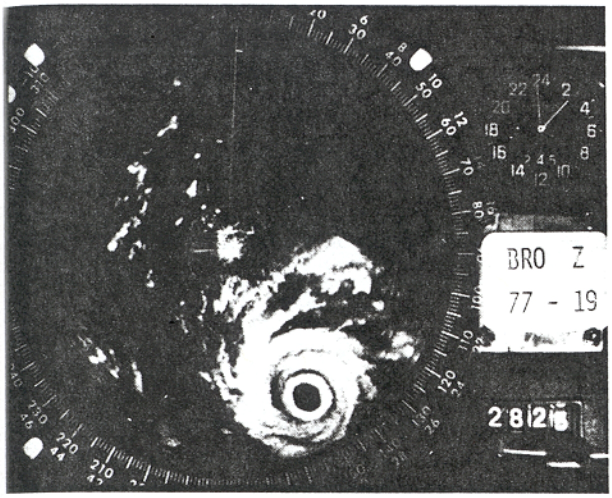

Fig. 8. Radar photograph of Hurricane Anita from Brownsville, Tex., 0300 GMT 2 September 1977.

mi south of the United States border and 24 n mi inland. An infrared satellite image is shown in Fig. 7 near the time of maximum intensity and several hours before landfall. A Brownsville radar photograph (Fig. 8) clearly depicts the extremely well-defined hurricane eye and eyewall early on 2 September.

4) Meteorological factors

Anita ranks as a strong category 4 on the Saffir/Simpson scale for a period of time just before landfall.[2] The pressure of 926 mb is the fourth lowest of record in the Gulf of Mexico, and the third lowest at landfall.

The following factors appear to have provided the opportunity for Anita to develop to such an intense storm. First, the rather slow forward speed of movement (discussed earlier) allowed for almost 96 h of continuous strengthening over the warm waters of the Gulf of Mexico. Second, during this time, Anita was embedded in warm, moist tropical air and encountered no intrusions of nontropical air from further north. Fig. 9 shows the 500 mb chart for 0000 GMT 2 September 77. The ridge across the east-central United States to the north of Anita was well-developed. This was the case all during Anita's history in the Gulf.

Another point of interest in Fig. 9 concerns the extension of the high pressure ridge southwestward across Texas and into northern Mexico. This feature is responsible for Anita's change to a heading of 235° (see previous subsection).

On 25 August, several days prior to Anita's formation, the NOAA ship *Researcher* measured an eddy in the sea surface temperature field in the north central Gulf of Mexico. This eddy was, in some locations, as much as 1°C warmer than the surrounding waters. This feature is considered to be part of a unique data set and it is hoped that it may provide insight into the intensification mechanism.

Finally, an experimental criterion for storm development (Shapiro, 1977) indicated favorable conditions in the Gulf of Mexico several days before Anita's arrival.

5) Damage and casualties

Mexican newspapers reported that inland floods and landslides killed 10 persons in an area of Mexico from La Pesca inland to Ciudad Victoria.

[2] A scale has been developed by H. Saffir and R. H. Simpson that ranks hurricanes from 1 to 5, where category 1 is a minimal hurricane and category 5 is for sustained winds greater than 155 mph. At the National Hurricane Center, storms of category 3 or higher are referred to as major hurricanes.

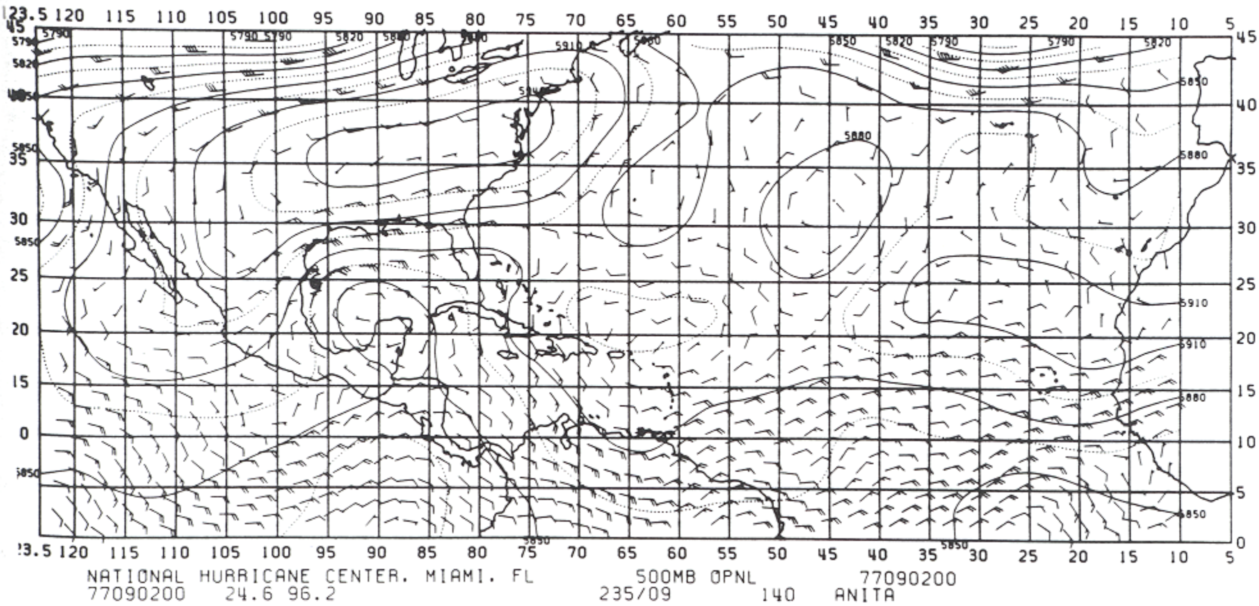

Fig. 9. 500 mb geopotential heights (m) and winds (kt) for 0000 GMT 2 September 1977. The hurricane symbol near 25°N, 96°W indicates the position of Hurricane Anita.

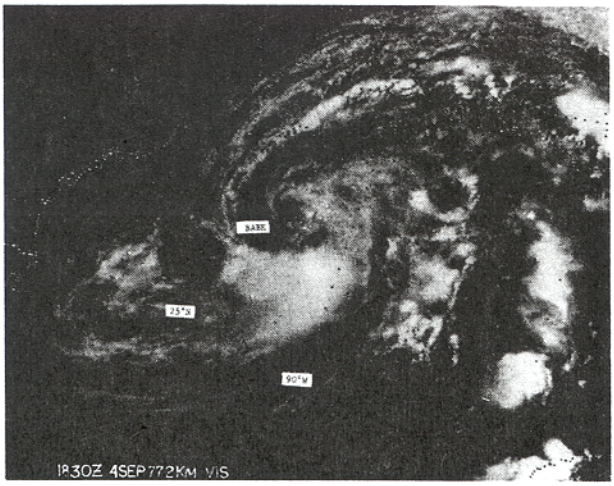

FIG. 10. Visible satellite picture of Babe at 1830 GMT 4 September 1977 from GOES-2 (1 n mi resolution).

The portion of the Mexican coast that was most affected by the hurricane is sparsely settled and damage estimates are not available. It can be stated that *extensive* losses were sustained by inhabitants of fishing and farming communities in the path of the storm.

South Texas rainfall was approximately 2 inches. Mexican totals are not known, but a report from Soto La Marina indicated a 6 h total of 17.52 inches.

Almost 100 000 people evacuated coastal locations. Of this, 35 000 were from along the Mexican coast. The remainder were from Texas and Louisiana including 7000 workers from offshore oil drilling platforms.

b. Hurricane Babe, 3–8 September

1) METEOROLOGICAL HISTORY

The formation of Babe resulted from the interaction between an African wave and a cold upper low. The wave moved into the Atlantic from Africa on 23 August and reached the Gulf of Mexico on 2 September, where a 200 mb low was located over the extreme northeast Gulf. On 3 September, the 200 mb low had moved to the central Gulf of Mexico and westerly surface winds at data buoy EB-44 (26°N, 86°W) confirmed that a surface low had formed in the east central Gulf.

Convection was not concentrated near the low center, but extended in a band from the central Gulf to the mouth of the Mississippi River, then eastward to just offshore of the Florida panhandle. Gale-force winds within this band of convection led to the designation of Babe as a tropical storm. Gale warnings were posted from Morgan City, La., to Pensacola, Fla., at 1600 GMT 3 September. This action was taken even though the system had not acquired tropical structure, in order not to confuse the public at a time of immediate threat.

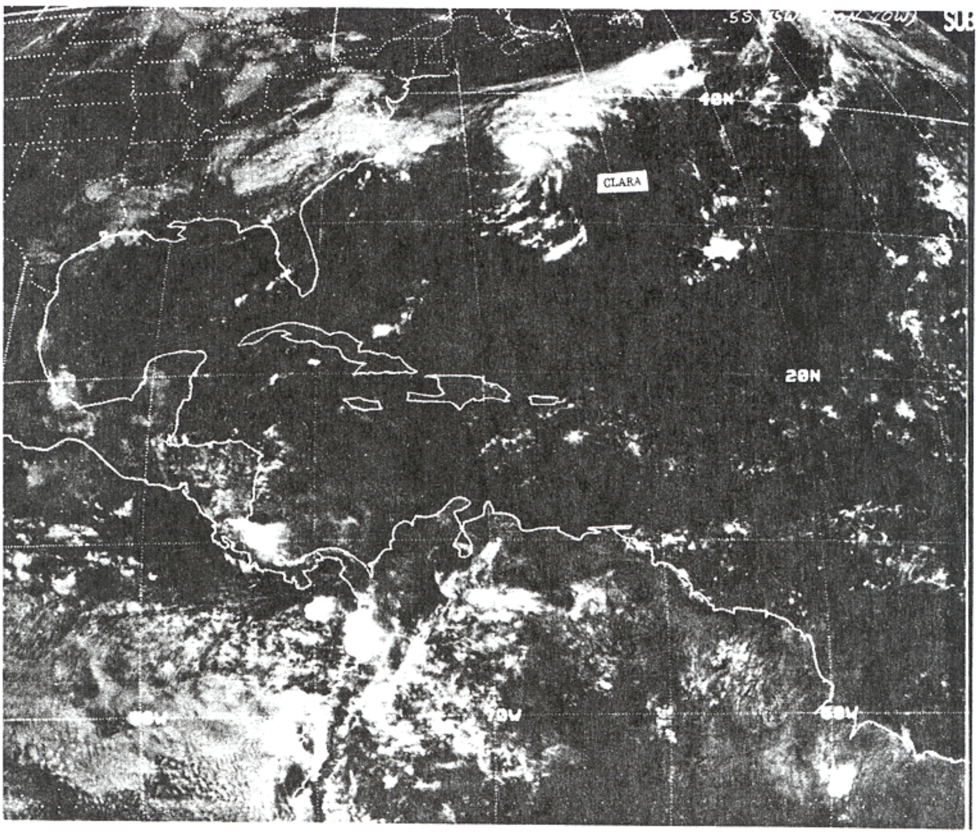

FIG. 11. Visible satellite picture of Clara at 1400 GMT 8 September 1977 from GOES-2 (2 n mi resolution).

Early on 4 September, the band of convection and strong winds moved inland and weakened. Interest shifted to the central Gulf, where the strongest winds were drawing in closer to the low center. The upper flow over this system was now anticyclonic and the transition to a warm core tropical storm was completed by midday on 4 September.

The storm had been moving west to southwest, but large 24 h pressure falls along the central Gulf coastal states diminished this westward steering. This, combined with large pressure falls over east Texas and small rises over Florida, resulted in a northward movement by the afternoon of 4 September.

At 1903 GMT 4 September, an Air Force reconnaissance aircraft reported a 70 kt surface wind 55 n mi southeast of the storm center. It is now evident that these winds were associated with a narrow band of strong convection well removed from the center, were transitory and were not representative of the strength of the system. The same report showed the lowest pressure to be 1000 mb, well above that generally believed to be required for sustained winds of hurricane strength with the existing peripheral pressures. Fig. 10 shows a satellite picture of Babe at 1830 GMT 4 September, very near the time of the reconnaissance report.

Babe continued northward and made landfall on the morning of 5 September. Winds decreased rapidly thereafter and the storm was reduced to a depression by midafternoon of the same day.

2) WARNINGS

Gale warnings were issued on 3 September in connection with a band of convection along the north central Gulf of Mexico coast.

TABLE 2. Meteorological data of Hurricane Babe, 3–8 September 1977.

Station	Date	Pressure Inches	Pressure Time[a]	Wind (mph) One min average	Wind Time[a]	Peak gust	Time[a]	Tide (ft) Height MSL	Tide Time[a]	Rainfall (inches) Storm total
Alabama										
Mobile	6	29.81	0258			S 36	0719	2.9[b]	0720	
Lousiana										
Baton Rouge	5	29.55	2154			40	0048			5.56
Boothville	5	29.75		44						
Grand Isle CG	5					SE 53	0030			
Lafayette	5	29.60				34				
Lake Charles	5	29.72	1600	N 21		29	1507	3.9[b]		0.31
Lockport	5	29.76	1300	35[c]		45[c]				4.95
Moisant Airport	5	29.68	0437	E 18	0353	E 31	0355			3.27
Morgan City	5	29.45	0500							
Morgan City Steam Plant	5					NE 39				
New Iberia										4.08
New Orleans Lakefront Airport	5					SE 44				
New Orleans WSFO	5	29.71	0410			ESE 37	1233			2.90
Atchafalaya Bay at Eugene Isle								2.55		
Bayou Bienvenue Floodgate East								4.55		
Bayou Dupre Floodgate East								4.31		
Bayou Lafourche at Leeville								4.05		
Bayou Petit Caillou								8.66[c]		
Belle Isle								2.34		
Canal Lock Seabrook Bridge								4.43		
Intracoastal WW Paris Road								4.77		
Lake Borgne near Chef Menteur								3.71		
Lake Pontchartrain										
near Rigolets								3.3		
at Irish Bayou								4.54		
at West End								3.88		
at Frenier								4.21		
at Mid Lake								4.34		
Mississippi River										
at Venice								3.4		
at Gulf Outlet								5.03		
Round Bayou										
at Dear Isle								3.37		
Mississippi										
Merrill										6.10

[a] Central Standard Time.
[b] Height above normal.
[c] Estimated.

By 0000 GMT 5 September, shortly after receipt of the 70 kt reconnaissance report, the storm center was only 70 n mi from the Louisiana coast. Since some slight strengthening had been indicated by reconnaissance reports and satellite pictures, it was already after dark, and the center of the storm was expected to reach the coast by daybreak, it was decided to take the course of least regret and designate Babe as a hurricane. Hurricane warnings were posted at that time from Vermilion Bay, La., to the mouth of the Mississippi River. Post analysis does not demonstrate that hurricane strength was reached before 0600 GMT on 5 September, when Air Force reconnaissance reported a central pressure of 995 mb. Maximum sustained winds over water are not believed to have exceeded 65 kt, and it is doubtful that any hurricane-force winds occurred over land.

3) Damage

The highest wind reported on land was a Coast Guard reading of a gust to 46 kt at Grand Isle, La. It is felt that higher wind speeds occurred closer to the storm center. Highest sustained wind reported was 40 kt at Boothville. Table 2 contains the available meteorological data concerning Babe.

A number of tornadoes occurred after the storm moved inland. On 5 September six were reported in southeastern Louisiana and three in southern Mississippi. One or possibly more tornadoes occurred on 6 September near Tuscaloosa, Ala.; as the depression approached that area, and there was a report of a possible tornado in northwestern Georgia on the afternoon of 7 September.

Highest tide readings were generally near 5 ft above mean sea level in southeast Louisiana. This resulted in some flooding. However, water levels were already somewhat above normal, since Anita had passed by this area only several days earlier.

The remnants of Babe traveling across the southeastern states caused considerable flash flooding. Up to 7 inches of rain fell over the mountain areas of Tennessee and the Carolinas, and up to 4 inches elsewhere.

Babe's damage estimate is $10 million, mostly in southern Louisiana. Property damage was primarily the result of coastal flooding. Crop damage, mainly sugar cane, was caused by heavy rain and wind. Evacuation estimates for the low-lying areas of coastal Louisiana are in the 20 000–30 000 range. No fatalities have been reported.

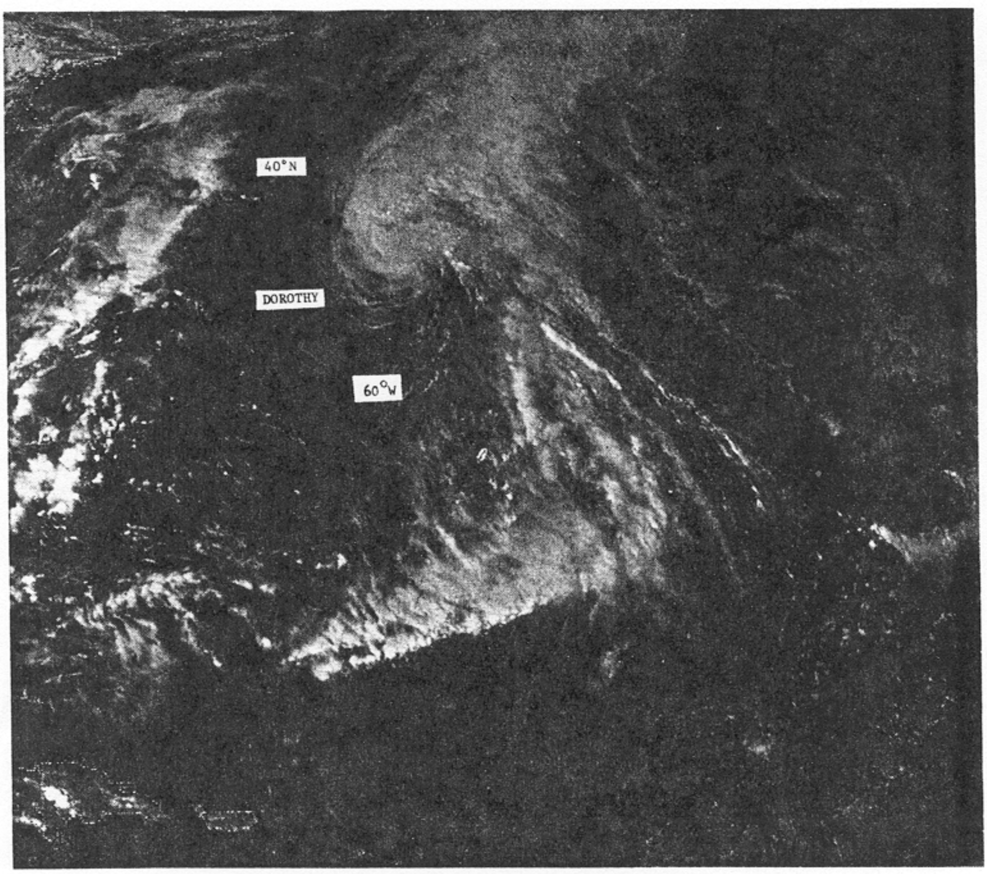

Fig. 12. Visible satellite picture of Dorothy at 1830 GMT 28 September 1977 from GOES-2 (1 n mi resolution).

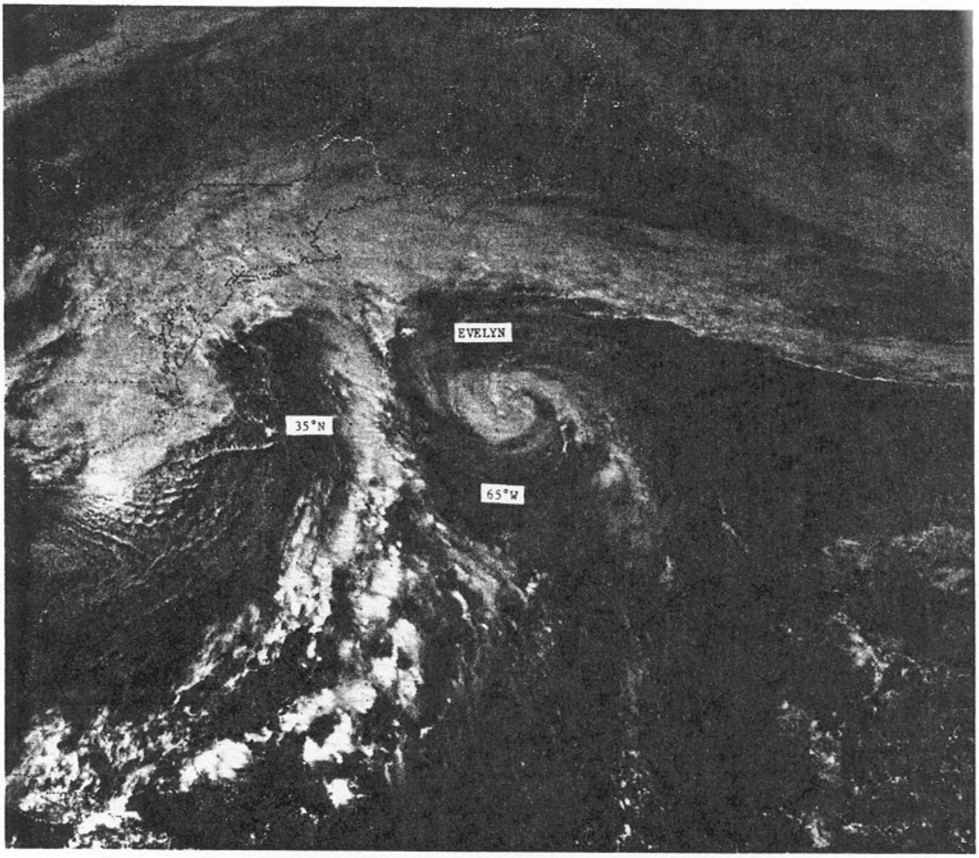

FIG. 13. Visible satellite picture of Evelyn at 1730 GMT 14 October 1977 from GOES-2 (1 n mi resolution).

c. Hurricane Clara, 5–11 September

Clara's origin was unusual. The cloud system within which it developed was a convective band containing gale force winds and was associated with the early stages of Babe. On 4 September, as this system moved over southeast Georgia, a weak mid-tropospheric circulation formed. By 1200 GMT 5 September, this circulation was affecting the surface and a depression became located just north of Charleston,. S. C. Charleston reported a west surface wind and a 24 h pressure fall of 4 mb. This depression drifted east-northeastward during the next 36 h, slowly becoming better organized.

The depression was located a short distance south of Cape Hatteras late on 6 September when it accelerated and began strengthening. Clara reached storm intensity by 0000 GMT 8 September when the center was 200 n mi east of Cape Hatteras. The lowest sea level pressure of 993 mb and maximum sustained winds of 65 kt were reached on the morning of 8 September. Clara is pictured in Fig. 11 near the time of maximum strength.

The central pressure began to rise as a trough in the westerlies which had caused Clara to accelerate, passed to the north and east. Reconnaissance aircraft reported that hurricane-force winds continued for at least 12 more hours after the lowest pressure was reached.

Strong high-level winds over the center caused continued weakening as convection was sheared off toward the east. Clara turned southeast and traversed a tight loop (Fig. 1) before accelerating northeastward. The storm was absorbed in an extratropical low pressure system on 11 September several hundred miles northeast of Bermuda.

Clara briefly threatened Bermuda on 10 September while a minimal tropical storm, but no gales were reported from the island. There are no known casualties or damages in connection with Clara.

d. Hurricane Dorothy, 26–30 September

Hurricane Dorothy is associated with a tropical wave that entered the eastern Atlantic in mid-September. This wave passed through the central Lesser Antilles on 21 September with thunderstorm gusts to 60 kt reported at Guadeloupe and Martinique. Rainfall amounts in this region were 5–8 inches and there was some flash flooding.

This heavy weather is attributed to high-level divergent flow associated with the east side of a 200 mb trough located over the eastern Caribbean. As the wave moved westward, directly under the trough, the convection diminished and the wave weakened.

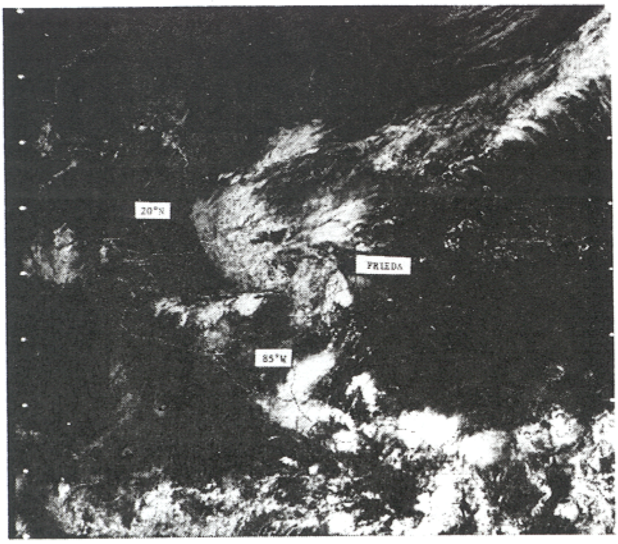

FIG. 14. Visible satellite picture of Frieda at 1401 GMT 17 October 1977 from GOES-2 (1 n mi resolution).

After crossing Hispaniola on 23 September, the weather system associated with the wave moved northward through the eastern Bahamas. This change in direction was caused by the presence of a stationary frontal trough off the southeastern United States. On the afternoon of 25 September, a low pressure system developed within the disturbed weather and became a tropical depression on 26 September to the north of the Bahamas. The depression by this time was moving northeastward at 10–15 kt and it strengthened to a tropical storm on the morning of 27 September with 45 kt and 1000 mb as measured by reconnaissance aircraft.

Dorothy reached hurricane force on the morning of 28 September. It then accelerated to a forward speed of 20 kt as a major trough approached from the west. Tropical characteristics were lost as Dorothy moved over colder waters. The remnants were absorbed by a frontal low pressure system to the east of Newfoundland on 30 September.

Maximum storm strength was estimated at 980 mb and 75 kt on the evening of 28 September. Fig. 12 is a satellite picture of Dorothy at 1830 GMT of that day. The only problems in connection with Dorothy were in the form of a threat to North Atlantic shipping lanes.

e. Hurricane Evelyn, 13–15 October

In a manner similar to Dorothy, Hurricane Evelyn had its origin as a tropical wave which interacted with an upper level cold low. This interaction occurred on 12 October in the southwest North Atlantic. As the upper low passed southward, the high-level circulation pattern became favorable for development and satellite pictures indicated that a surface depression had formed on 13 October, 400 n mi south of Bermuda.

The depression headed toward Bermuda, and at 0920 GMT 14 October the Naval Air Station on the island recorded a wind shift and minimum pressure of 1003.8 mb. This, as well as some earlier ship reports, allowed a determination that Evelyn had become a tropical storm early on 14 October.

After crossing Bermuda, Evelyn accelerated north-northeastward in the strong flow to the east of an intensifying 500 mb low. Strengthening occurred as a forward speed of 30 kt was reached. An Air Force reconnaissance flight measured 994 mb central pressure and flight level winds of 72 kt at 0000 GMT 15 October. Based on these data, Evelyn was upgraded to a hurricane.

Meanwhile, an intense nontropical storm to the west was paralleling Evelyn's track. Fig. 13 shows a satellite picture of both Evelyn and the nontropical storm. Note that the frontal cloud band was approaching Evelyn from the west. Even after the front was merging with the storm, a ship reported 1001 mb and 68 kt (highest surface winds reported) near the southwest tip of Newfoundland at 1800 GMT 15 October.

The storm weakened rapidly as it crossed western Newfoundland, and no reports of damage or casualties have been received.

f. Tropical Storm Frieda, 16–18 October

Frieda was a short-lived tropical storm. Its origins can be traced to a tropical wave which passed off the African coast on 4 October 1977. It traveled westward for the next 10 days without incident. Then a large convective cloud mass associated with this wave moved from the central Caribbean on 14 October to the northwest Caribbean on 15 and 16 October.

Meanwhile, a cold front had moved across the Gulf of Mexico on 12 October and its remnants, a baroclinic zone of frontal cloudiness, became located in the northwest Caribbean. The cloudiness from the wave merged with the front on the 16th, and a second cold front moved into the same area soon after, apparently reinforcing the surface horizontal wind shear and temperature gradient in this region.

Late on 16 October a reconnaissance aircraft located a surface circulation center just east of Swan Island, and this was identified as a tropical depression. The center remained very well-defined until midday on 18 October. It moved steadily and slowly westward from its inception until late on 18 October when it crossed the coast of Belize in Central America just north of Belize City. For most of Frieda's duration, the associated circulation pattern was confined to the lower troposphere as evidenced by the lack of mid and upper cloudiness near the center. Fig. 14 shows this absence of cloudiness. Therefore, the storm's motion was controlled by the easterly trades which resulted in a steady westward course.

On 17 October a reconnaissance aircraft reported a band of strong westerly winds between the center and the north coast of Honduras. Winds of 60 kt were measured at a flight level of 1500 ft, 50 n mi south of the center. Surface winds of 50 kt were estimated at this same position.

It was the receipt of the above wind information that resulted in the upgrading of this depression to a tropical storm. Other factors contributing to this decision were 1) satellite pictures indicating a very well-defined low-level center and 2), the occasional heavy rainfall associated with this system—Swan Island reported 4.46 inches during a 30 h period and Grand Cayman had 5.42 inches during a 36 h period.

By the time of landfall, maximum winds had decreased to well below gale force. Belize City, just south of the point of landfall, had only light rain and light westerly winds. There have been no reports of damage or casualties.

Acknowledgments. Portions of the individual storm accounts were extracted from preliminary reports prepared by G. B. Clark, P. J. Hebert, J. R. Hope and Dr. J. M. Pelissier at the National Hurricane Center. R. Carrodus prepared the track chart. Drs. R. Burpee, L. Shapiro and P. Leftwich provided helpful guidance.

REFERENCES

Ballenzweig, E. M., 1958: Formation of tropical storms related to anomalies of the long-period mean circulation. Rep. No. 21, National Hurricane Research Project, U. S. Weather Bureau, 16 pp.

Landers, H., 1963: On the formation and development of tropical cyclones. *J. Appl. Meteor.*, **2**, 206–218.

Lawrence, M. B., and B. M. Mayfield, 1977: Satellite observations of trochoidal motion during Hurricane Belle 1976. *Mon. Wea. Rev.*, **105**, 1458–1461.

Namias, J., 1955: Secular flucuation in vulnerability to tropical cyclones in and off New England. *Mon. Wea. Rev.*, **83**, 155–162.

Norquist, D. C., E. E. Recker and R. J. Reed, 1977: The energetics of African wave disturbances as observed during phase III of GATE. *Mon. Wea. Rev.*, **105**, 334–342.

Shapiro, L. J., 1977: Tropical storm formation from easterly waves: a criterion for development. *J. Atmos. Sci.*, **34**, 1007–1021.

Taubensee, R. E., 1977: Weather and circulation of September 1977. *Mon. Wea. Rev.*, **105**, 1619–1625.

Atlantic Tropical Systems of 1977

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ABSTRACT

The 1977 hurricane season produced 105 "tropical systems", of which 19 acquired the closed circulation of a depression. Over half of these (69) originated over the African Continent. African seedlings initiated four of the six named Atlantic storms, and all but one of the eight east Pacific storms.

1. Introduction

This is the tenth consecutive year a seasonal tropical disturbance summary has been completed. The general philosophy of the counting method was outlined in previous articles by Simpson *et al.* (1968, 1969).

Lawrence (1978) describes the 1977 hurricane season as being "inactive". Thus, the current lull in hurricane activity being enjoyed by interests in the Atlantic continues. During the last six years the cause of the inactivity has generally been related to cool ocean temperatures and strong upper westerlies over the hurricane breeding grounds. In 1976 Hebert (1976) noted a trend toward normalcy for these two parameters, and this year Lawrence (1978) observed near-normal sea temperatures and upper winds over most of the tropical Atlantic. This would suggest an increase in storm activity. So what happened? Where were the storms?

It is interesting to note that tropical storm activity was also well below normal in the Pacific. This can be seen in Table 1 which compares the storm activity for both the Atlantic and Pacific in 1977 with longer period annual averages. The number of tropical storms in the Northern Hemisphere was around 30% below normal in 1977. This is a very interesting observation and suggests global circulation influences. Lawrence (1978) related the inactivity in the Atlantic to a weaker than normal subtropical ridge. This produced a weak north-south shear of the horizontal winds—another term found by many authors to be important in storm development. Data are not available at our Center to see if similar conditions were also true in the Pacific.

Table 1. Storm activity in 1977 compared with long-term averages.

	Named storms		Hurricanes	
	1977	Annual average	1977	Annual average
Atlantic	6	8 (1900–76)	5	5
East Pacific	8	15 (1966–76)	4	7
West Pacific	19	28 (1959–76)	11	19

2. Census of 1977 tropical systems

The systems observed during the 1977 hurricane season are given in Table 2, and results for several categories are summarized in Table 3 and Fig. 1.

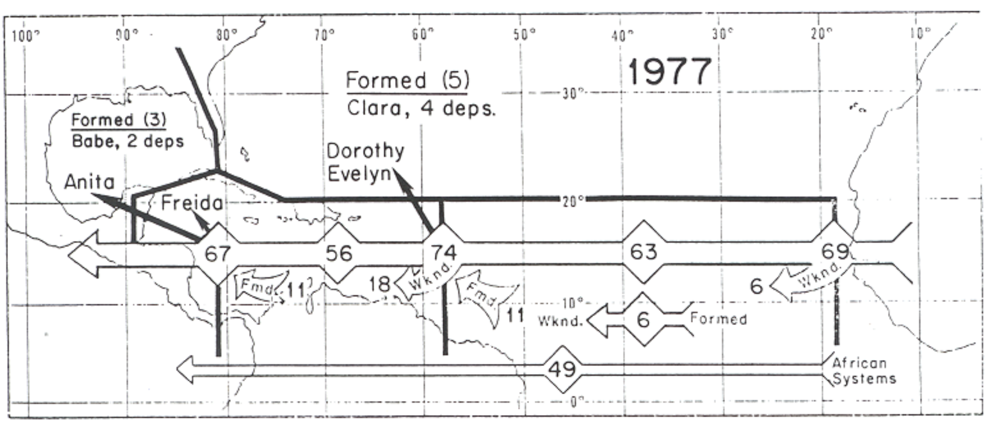

Fig. 1. Summary of tropical disturbances that passed three key stations (Dakar, Barbados, San Andres) in 1977 and those maintaining their identity while crossing the Atlantic and Caribbean.

TABLE 2. Summary of the tropical systems of 1977.

Dakar passage	Nature	Formed in Atlantic	Date weakened Atlantic	Date Barbados passage	Nature	Weakened Caribbean	Formed Caribbean	San Andres passage	Nature	Formed Gulf of Mexico	Formed North Atlantic	Atlantic depression	Atlantic storm	Pacific depression	Pacific storm
May 3	Wave			May 8	Wave			May 12							
May 4	Wave			May 11	Wave			May 15							
May 8	Wave			May 14	Wave			May 18						#1	Ava
		5/13	5/15												
May 11	Wave			May 20	Wave			May 25						#2	
May 16	Wave			May 25				May 29						#3	
		5/25		May 26	Wave			June 2	Wave		6/3	#1			
May 21	Wave			May 29	Wave	5/29									
May 26	Wave			June 1	Wave			June 4	Wave						
May 28	Wave			June 4	Wave			June 8	Wave	6/13		#2		#4	
May 30	Wave			June 7	Wave	6/7									
June 2	Wave			June 8	Wave			June 11	Wave						
June 3	Wave			June 10	Wave			June 14	Wave						
June 5	ITCZ			June 13	ITCZ			June 16	ITCZ						
June 8	Wave			June 15	Wave			June 18	Wave					#5	Bernice
June 10	Wave			June 16	Wave	6/16									
June 13	Wave			June 17	Wave			June 20	Wave						
											6/17	#3			
June 15	Wave			June 20	Wave			June 23	Wave						
							6/24	June 25	ITCZ					#6	
June 18	Wave			June 23	Wave			June 26	Wave						
June 21	Wave			June 26	Wave			June 28	Wave					#7	Claudia
June 23	Wave			June 27	Wave			June 30	Wave						
June 25	Wave			June 29	Wave			July 2	Wave					#8	
June 27	Wave			July 1	Wave			July 4	Wave					#9	
							7/3	July 5	ITCZ						
June 30	Wave			July 5	Wave			July 8	Wave						
July 3	Wave			July 10	Wave	7/11									
		7/3		July 8	Wave			July 12	Wave						
July 6	Wave			July 12	Wave			July 16	Wave	7/18		#4		#10	
July 8	Wave			July 14	Wave	7/15									
							7/17	July 19	ITCZ						
		7/14		July 16	Wave			July 21	Wave						
											7/21	#5			
July 12	Wave			July 19	Wave			July 23	Wave					#11	
July 15	Wave			July 22	Wave			July 25	Wave						
July 17	Wave			July 24	Wave	7/25									
										7/25		#6			
July 20	Wave			July 26	Wave			July 28	Wave						
July 22	Wave			July 29	Wave			August 2	Wave						
July 25	Wave			August 1	Wave			August 5	Wave						
July 28	Wave			August 4	Wave			August 7	Wave					#12	Doreen
							8/8	August 9	ITCZ						

TABLE 2 (*continued*)

Dakar passage	Nature	Formed in Atlantic	Date weakened Atlantic	Date Barbados passage	Nature	Weakened Caribbean	Formed Caribbean	San Andres passage	Nature	Formed Gulf of Mexico	Formed North Atlantic	Atlantic depres-sion	Atlantic storm	Pacific depres-sion	Pacific storm
												#7			
August 1	Wave			August 7	Wave			August 12	Wave						
							8/12	August 13	ITCZ						
								August 16	Wave						
August 6	Wave			August 12	Wave										
August 8	Wave			August 13	Wave	8/13									
August 9	Wave			August 15	Wave			August 19	Wave						
August 12	Wave			August 17	Wave			August 21	Wave						
August 14	Wave			August 20	Wave			August 24	Wave						
August 17	Wave			August 23	Wave			August 27	Wave	8/29		#8	Anita	#13	
		8/19	8/23												
August 20	Wave			August 27	Wave			August 31	Wave						
August 24	Wave			August 29	Wave			September 1	Wave						
August 25	Wave			August 30	Wave	8/31								#14	Emily
		8/29		September 2	Wave			September 6	Wave						
August 28	Wave			September 5	Wave			September 9	Wave						
		9/2	9/4												
										9/3		#9	Babe		
											9/3	#10			
											9/5	#11	Clara		
														#16	Florence
September 1	Wave			September 8	Wave			September 11	Wave						
September 3	Wave			September 10	Wave			September 13	Wave					#15	
		9/9		September 12	ITCZ			September 15	Wave						
September 5	Wave			September 14	Wave			September 17	Wave						
September 9	Wave		9/10											#17	Glenda
								September 20	Wave	9/22		#13			
September 10	Wave			September 17	Wave										
		9/13		September 19	Wave			September 22	Wave						
							9/23	September 24	ITCZ						
								September 27	Wave		9/26	#14	Dorothy		
September 12	Wave			September 21	Wave										
		9/21		September 23	Wave	9/24									
				September 25	Wave			September 28	Wave						
September 19	Wave													#18	Heather
				September 27	Wave			September 30	Wave						
September 23	Wave														
		9/25	9/27												
								October 2	Wave						
September 24	Wave			September 29	Wave										
											10/1	#16			
September 27	Wave			October 4	Wave	10/6									
September 30	Wave		10/3												
											10/2	#15			
							10/2	October 3	ITCZ						
							10/7	October 8	ITCZ						
														#19	
				October 7	Wave			October 11	Wave						
October 2	Wave										10/16	#18	Frieda		
				October 10	Wave			October 16	Wave						
October 3	Wave											#17	Evelyn		
				October 12	Wave	10/13		October 13	Wave						
October 6	Wave														
				October 15	Wave	10/16									
October 9	Wave														
				October 17	Wave	10/18									
October 10	Wave														

TABLE 2 (*continued*)

Dakar passage	Nature	Formed in Atlantic	Date weakened Atlantic	Date Barbados passage	Nature	Weakened Caribbean	Formed Caribbean	San Andres passage	Nature	Formed Gulf of Mexico	Formed North Atlantic	Atlantic depres-sion	Atlantic storm	Pacific depres-sion	Pacific storm
October 12	Wave			October 18	Wave			October 22	Wave						
		10/15		October 22	ITCZ	10/21									
		10/20		October 23	ITCZ	10/23									
October 17	Wave			October 24	Wave	10/25									
		10/20	10/23												
										10/24		#19			
		10/29	10/31												
October 20	Wave			October 27	Wave			October 30	Wave						
October 23	Wave			October 29	Wave			November 2	Wave						
October 25	Wave			November 1	Wave	11/2									
October 30	Wave		10/31												
		10/30		November 4	ITCZ	11/6									
November 1	Wave		11/3												
							11/4	November 5	ITCZ						
							11/5	November 7	ITCZ						
							11/7	November 9	ITCZ						
		11/6		November 10	Wave			November 13	Wave						
November 4	Wave			November 14	Wave			November 17	Wave						
November 10	Wave		11/14												
November 13	Wave		11/17												

TABLE 3. Summary of 1977 tropical systems according to type and geographical area of formation. The numbers in parentheses indicate systems that were counted in a weaker stage.

	Africa	Tropical Atlantic	Sub-tropical Atlantic	Caribbean	Gulf of Mexico	Total
Waves	68	7	0	0	0	75
ITCZ	1	10	0	11	0	22
Depression	0	(3)	5 (2)	(2)	3 (4)	8 (11)
Named storms	0	7	(3)	(1)	(2)	(6)
Total	69	17 (3)	5 (5)	11 (3)	3 (6)	105 (17)

Table 2 describes the history of the 105 systems, giving the dates when they passed three key stations: Dakar, Senegal, Barbados and San Andres Island. The table also lists the spawning date of seedlings that formed and weakened along the intertropical convergence zone (ITCZ) in the Atlantic, and the dates of formation of subtropical cyclones or depressions over the Gulf of Mexico and the Atlantic north of 20°N. The Atlantic and eastern Pacific storms that were initiated by Atlantic seedlings are listed in the last four columns.

Table 3 summarizes the systems according to type and geographical area of formation. The numbers in parentheses indicate systems that were counted in a weaker stage of development. For example, Evelyn and Dorothy formed in the tropical Atlantic north of 20°N and were initiated by African waves. Once again, we see that nearly half the systems were wave perturbations in the trades whose origin was over Africa. This observation has been true every year we have completed the survey, and stresses the importance of Africa as a seed-bed for Atlantic disturbances.

Fig. 1 tabulates the total number of systems passing Dakar, Barbados and San Andres Island as well as the number that maintained their identity while traversing the Atlantic and Caribbean. Statistics are also presented on the seedlings that developed within four geographical areas: the Gulf of Mexico, the Caribbean Sea, and the subtropical and tropical Atlantic, where latitude 20°N has been used as a dividing line. Of the 69 African systems, 63 were tracked to the Caribbean and 49 all the way to the Pacific. Over the tropical Atlantic, 17 disturbances formed with 11 eventually passing through the Antilles. Six of these were identified along the ITCZ and were followed for at least 48 h before dissipating. A total of 74 systems crossed the Antilles (63 from Africa plus 11 that formed in the Atlantic) of which 56 maintained their identity while traversing the Caribbean. The 11 disturbances that formed over the Caribbean added to the number from the Antilles resulted in 67 seedlings entering Central America.

TABLE 4. Monthly distribution of depressions for 1977 compared with the 10 year averages.

	Jun	Jul	Aug	Sep	Oct	Nov	Total
10-year average (1967–76)	2.5	3.5	6.0	7.5	4.0	0.5	24
1977	3	3	2	6	5	0	19

TABLE 5. Results of 1977 compared with averages and ranges for the previous nine years (1968–1976).

	9-year average (1968–76)	Range	1977
Total systems (all types)	103	85–113	105
Dakar systems	58	52–68	69
Barbados systems	58	44–72	74
San Andres systems	52	40–64	67
Depressions*	25	22–34	19
Named storms	8	4–13	6
Subtropical storms	—	—	0

* This is the total number of depressions while Table 4 refers to depressions during the hurricane season only (June–November).

One unusual aspect of the 1977 season was the early appearance of several well-defined African waves. The first wave of the season moved by Dakar on 3 May. A third African system in early May was tracked all the way to the eastern Pacific where it spawned Ava, their first named storm of the year. African systems do not generally occur until mid or late May.

The depression tracks for the months June through October are shown in Fig. 2. The first depression of the season was initiated in early June by an African wave in the northwest Caribbean. The last depression of the

TABLE 6. Summary of the type of seedling that initiated Atlantic named storms and depressions during 1977 compared with annual averages from previous years.

Year	Tropical: African systems	Tropical: Disturbance	Baroclinic: Upper troposphere	Baroclinic: Lower troposphere	Totals
Named storms					
1977	3	1	1	1	6
10-year average (1967–76)	4	2	1	1	8
Active period (1967–70)	4	3	1	1	9
Inactive period (1971–76)	4	1	2	2	9
Depressions*					
1977	10	1	3	5	19
10-year average (1967–76)	10	3	4	7	24
Active period (1967–70)	13	5	3	4	25
Inactive period (1971–76)	9	2	4	8	23

* Only the depressions that occurred from June through November.

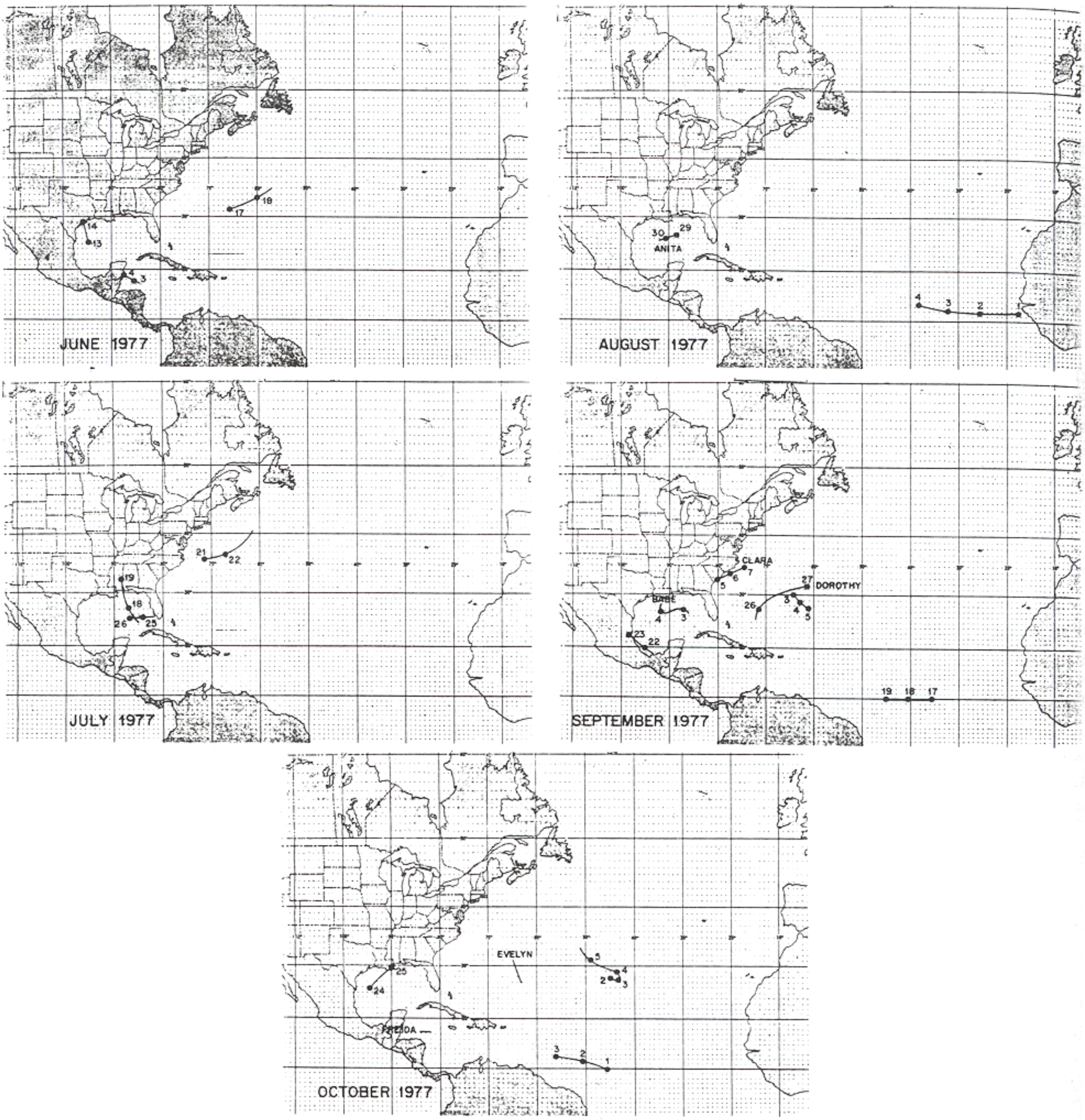

FIG. 2. Tracks of 1977 depressions.

year developed in October along an old baroclinic zone in the Gulf of Mexico.

This was the fewest number of depressions observed since 1967 when seasonal summaries were initiated. Two factors are related to this decrease in depression activity. First, there was a sharp drop in the number of depressions during the early peak of the hurricane season. This is seen in Table 4 which compares the monthly distributions of depressions for 1977 with the previous 10-year averages (1967–76). There were fewer depressions than normal in both August and September. The two depressions in August represent only one-third of the expected number. The second factor is related to the geographical area of formation. Over two-thirds (14) of the depressions formed over the subtropical latitudes of the Gulf of Mexico and the North Atlantic. Only three depressions developed in the tropical Atlantic south of 20°N, where we normally expect between eight to ten.

Fig. 3 summarizes the source of eastern Pacific named storms. The eight storms in the eastern Pacific were the fewest in number since our counting system began in 1968, and represent only half of the expected number. All but one of the eight storms were initiated

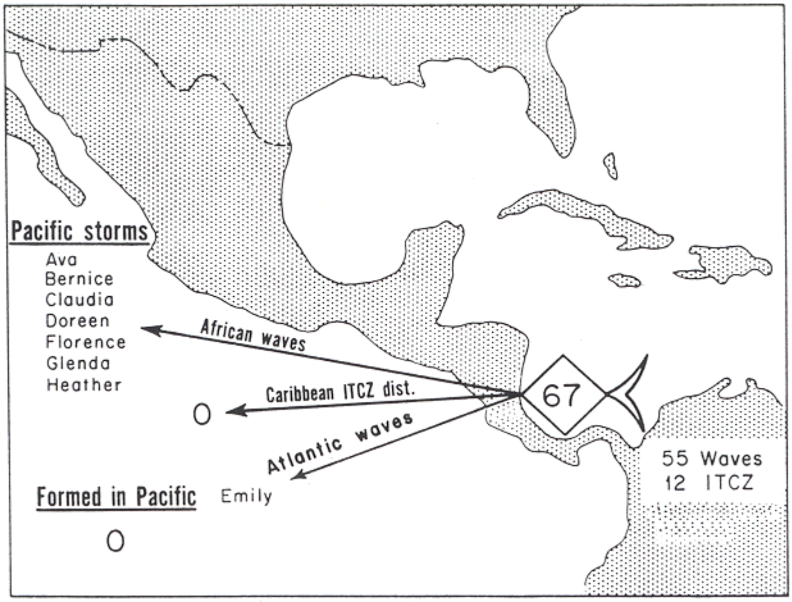

FIG. 3. Summary of the type of seedlings that initiated east Pacific storms in 1977.

by African disturbances. Again we see the dominant role played by African disturbances on the storm activity in the eastern Pacific.

3. Comparison with other years

Table 5 compares the tropical system in 1977 with averages and ranges determined over the previous nine years within several categories. The hurricane season in 1977 was a very interesting paradox. We have already seen that the named storms in eastern Pacific and Atlantic depressions were well below normal. The same is true of named storms in the Atlantic. Yet, the total number of systems was near normal, and the number of disturbances passing our three key locations was the highest in our 10-year history.

Table 6 summarizes the source of Atlantic depressions and named storms in 1977 compared with previous years. In the tables, the 1977 results are compared to averages for the past 10 years and to an "active" versus "inactive" period. The past 10 years can be divided into two periods. The years from 1967 to 1970 were characterized by normal storm activity, and the past six years have been relatively quiet. While the number of depressions and named storms initiated by "tropical-type" disturbances in 1977 was below normal and typical of what we have observed during the inactive period of the past six years, the activity spawned by "baroclinic-type" disturbances was more typical of the "active periods". This combination produced a 25% reduction from normal in the number of depressions and named storms.

In conclusion, the 1977 hurricane season can be characterized by many disturbances, but few storms. This interesting paradox emphasizes the controlling influence of environmental conditions in tropical storm development. It appears that a large-scale hemispheric circulation pattern produced a weaker than normal subtropical high over the oceans. The resulting north-south shear of the lower tropospheric wind was reduced and lessened the threat of tropical storm development.

REFERENCES

Hebert, P. J., 1976: Atlantic hurricane season of 1975. *Mon. Wea. Rev.*, **104**, 453–465.

Lawrence, M. B., 1978: Atlantic hurricane season of 1977. *Mon. Wea. Rev.*, **106**, 534–545.

Simpson, R. H., Neil L. Frank, David Shideler and H. M. Johnson, 1968: Atlantic tropical disturbances of 1967. *Mon. Wea. Rev.*, **96**, 251–259.

——, —— and ——, 1969: Atlantic tropical disturbances of 1968. *Mon. Wea. Rev.*, **97**, 240–255.