Atlantic Hurricane Season of 1976

MILES B. LAWRENCE

National Hurricane Center, National Weather Service, NOAA, Miami, Fla. 33124

ABSTRACT

A summary of the 1976 Atlantic hurricane season is presented along with detailed accounts of individual storms.

Interesting aspects of the 1976 season include the absence of any named storms in either the Gulf of Mexico or Caribbean Sea. Two storms in the central north Atlantic recurved toward the east at unusually low latitudes. Hurricane Belle struck Long Island after weakening dramatically during the 24 h period prior to landfall.

1. General summary

There were eight named tropical cyclones in the north Atlantic during the 1976 hurricane season. Of these, six reached hurricane force. In addition, three systems were identified as subtropical storms. Tracks of the tropical and subtropical cyclones are shown in Figs. 1 and 2, respectively, and statistical summaries are given in Tables 1 and 2.

The annual average for the past 30 years is nine storms, including six hurricanes. Therefore, tropical cyclone activity in 1976 was near normal. The number of hurricane days in 1976 was 26, for the second consecutive year (Hebert, 1976). This compares with a yearly average of 29 hurricane days over the past two decades (Hope, 1975).

It has been customary in recent years to refer to sea-surface temperatures and to the vertical shear of the horizontal wind as factors controlling tropical cyclone development. Mid-season sea-surface temperatures were near or above normal over the location of formation of this season's storms. In all cases, the named storms developed in regions of water temperatures greater than 27°C.

Initial development also occurred in areas of mid-season vertical shear less than 10 kt. This agrees with previous experience concerning this relationship. The only other noteworthy feature concerning mid-season vertical shear is a small area of shear values greater than 10 kt located over the western Caribbean. (Vertical shear is computed by subtracting the 1000–600 mb mean wind from the 600–200 mb mean wind.) It may be that the absence of activity in the Caribbean and Gulf of Mexico is related to this feature.

The lack of storms in both the Caribbean and Gulf of Mexico in a single season is a highly anomalous feature. It has occurred in only one other year (1962) since 1900. Inactivity in this area near the end of the hurricane season (October and November) resulted from early intrusions of cold air into the Gulf of Mexico and northwest Caribbean. This is supported by the fact that during October unusually cold air masses dominated most of the United States east of the Rocky Mountains (Wagner, 1977).

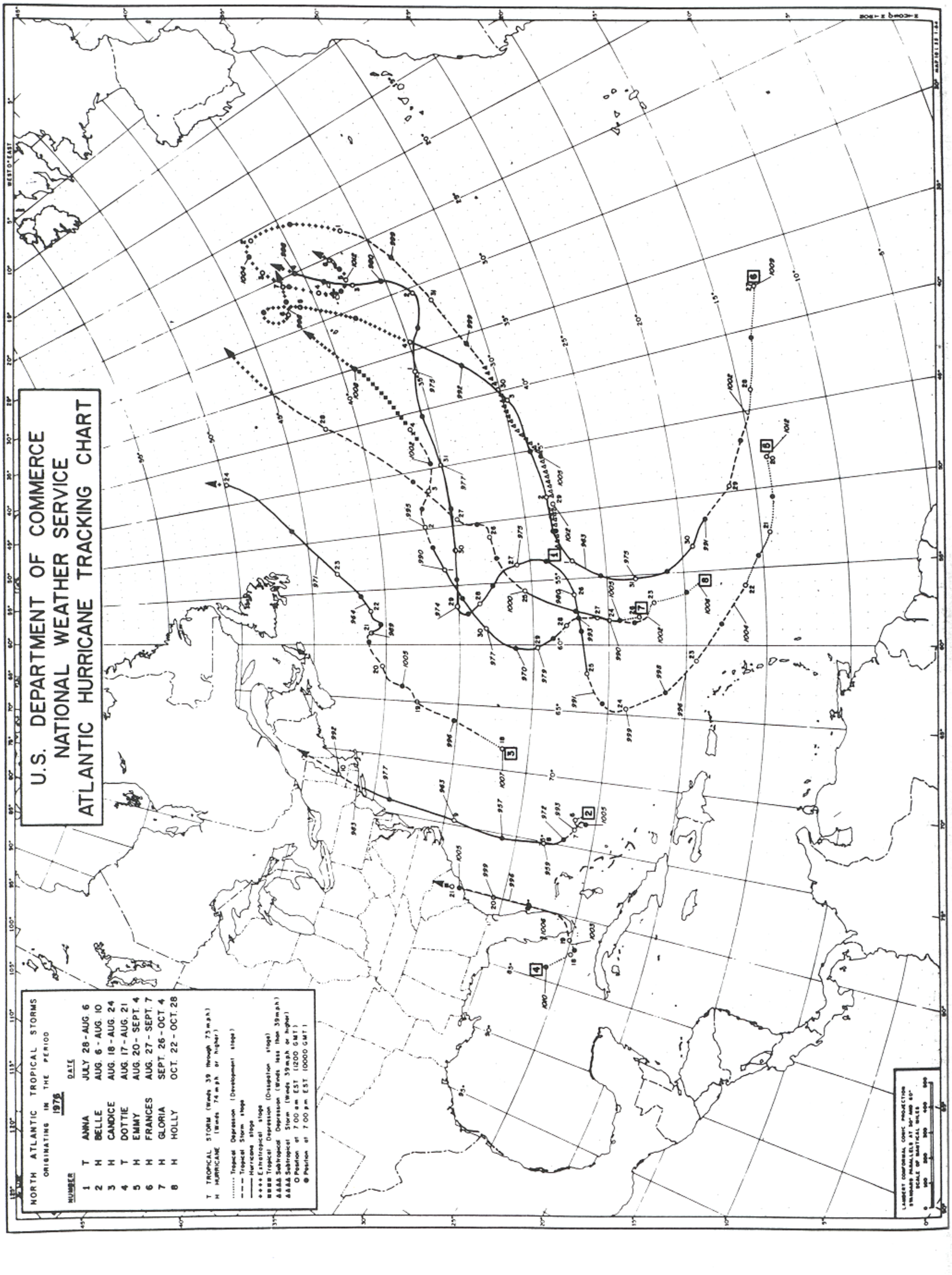
While high vertical shear and cold temperatures can at least partially account for a reduction in tropical storm development in a particular region, the complete lack of activity also implies that no storms pass through the area. Examination of the storm tracks (Fig. 1) reveals that several named storms formed to the east of the Antilles, but moved north before entering the Caribbean. Although not in itself unusual, this circumstance plus the early intrusion of cold air mentioned above and strong vertical shears may account for the anomalous absence of storms in both the Caribbean and Gulf of Mexico.

There is one aspect of the recurvature of Emmy and Frances (see Fig. 1) that is quite unusual. Inspection of storm tracks for the past hundred years reveals that the extreme southern latitude of recurvature in both cases is almost unprecedented so early in the season.

Although the synoptic situations associated with individual storms will be discussed in Section 2, it is worth noting here that the anomalous recurvature of Emmy and Frances was related to certain large-scale circulation features. Fig. 3 is a map of 500 mb geopotential height departures from normal for the month of August together with average winds. Normal in this case refers to a 15-year average of geopotential heights taken from data tapes made available to the National Hurricane Center.[1]

Fig. 3 shows a large negative anomaly (<-70 m) centered over the eastern North Atlantic and extending southwest and then westward along 25°N latitude.

[1] An interim note (unpublished) on Northern Hemisphere climatological grid data tape by H. L. Crutcher (Environmental Data Service, NOAA) and R. L. Jenne (National Center for Atmospheric Research), 1969.


U.S. DEPARTMENT OF COMMERCE
NATIONAL WEATHER SERVICE
ATLANTIC HURRICANE TRACKING CHART
NORTH ATLANTIC TROPICAL STORMS
ORIGINATING IN THE PERIOD
1976
NUMBER
DATE
1 T ANNA JULY 28 - AUG. 6
2 H BELLE AUG. 6 - AUG. 10
3 H CANDICE AUG. 18 - AUG. 24
4 T DOTTIE AUG. 17 - AUG. 21
5 H EMMY AUG. 20 - SEPT. 4
6 H FRANCES AUG. 27 - SEPT. 7
7 H GLORIA SEPT. 26 - OCT 4
8 H HOLLY OCT. 22 - OCT. 28
T TROPICAL STORM (Winds 39 through 73 m.p.h.)
H HURRICANE (Winds 74 m.p.h. or higher)
Tropical Depression (Development stage)
Tropical Storm stage
Hurricane stage
Extratropical stage
Tropical Depression (Dissipation stage)
Subtropical Depression (Winds less than 39 m.p.h.)
Subtropical Storm (Winds 39 m.p.h. or higher)
Position at 7:00 a.m. EST (1200 GMT)
Position at 7:00 p.m. EST (0000 GMT)

This negative anomaly represents a mean trough position whose presence was related to the drought-producing mean 700 mb blocking ridge over western Europe. According to Dickson (1976), this departure from normal is without precedent in a series of mean 700 mb analyses beginning in 1948. In any case, the southerly intrusion of mid-tropospheric westerlies associated with the negative anomalies in the central North Atlantic is responsible for the unusually early recurvature of Emmy and Frances.

Ballenzweig (1958) has related above normal hurrican activity tô monthly mean 700 mb height anomalies. He divides the tropics into zones one of which is the eastern Atlantic (east of 50°W longitude). At least two named storms must originate in a zone in a given month in order for the event to qualify as above normal. This happened in the eastern Atlantic during the 1976 season as Emmy and Frances formed there.

Ballenzweig found that formation in this area is associated with 700 mb heights below normal over most of the Atlantic south of latitude 30°N. Dickson (1976) found this to be the case this past August. It is necessary to point out, however, that Ballenzweig's below-normal heights are associated with a well-developed subtropical ridge being located north of normal. As noted above, the 1976 season negative height anomalies are a result of westerlies appearing at a location south of normal.

Finally, two named storms (Belle and Dottie) made landfall along the U. S. coast this season, albeit Dottie just barely qualified. This was the first time since 1971 that more than one storm hit the United States.

2. Individual named storms

a. *Tropical Storm Anna, 28 July–6 August (subtropical storm no. 2)*

The first named storm of the 1976 season began as a subtropical depression late on 28 July, several hundred miles southeast of Bermuda. As the system moved toward the east-northeast, it gradually strengthened, reaching subtropical storm force early on 30 July, approximately 1000 n mi southwest of the Azores.

A ship, M/S *Pointe Allegre*, confirmed the presence of the second subtropical storm of the season by passing through the center at 0200 GMT 30 July. This vessel reported a barometric fall from 1014 to 999 mb followed by a rapid rise to 1010 mb, all of this within a 1 h period. The ship experienced heavy thunderstorms with gusts to 60 kt and winds shifting from southeast to south-southwest to northwest.

The storm continued toward the east-northeast and began to rapidly acquire tropical characteristics, as inferred from satellite pictures. It was named Tropical Storm Anna on the afternoon of 30 July and then con-

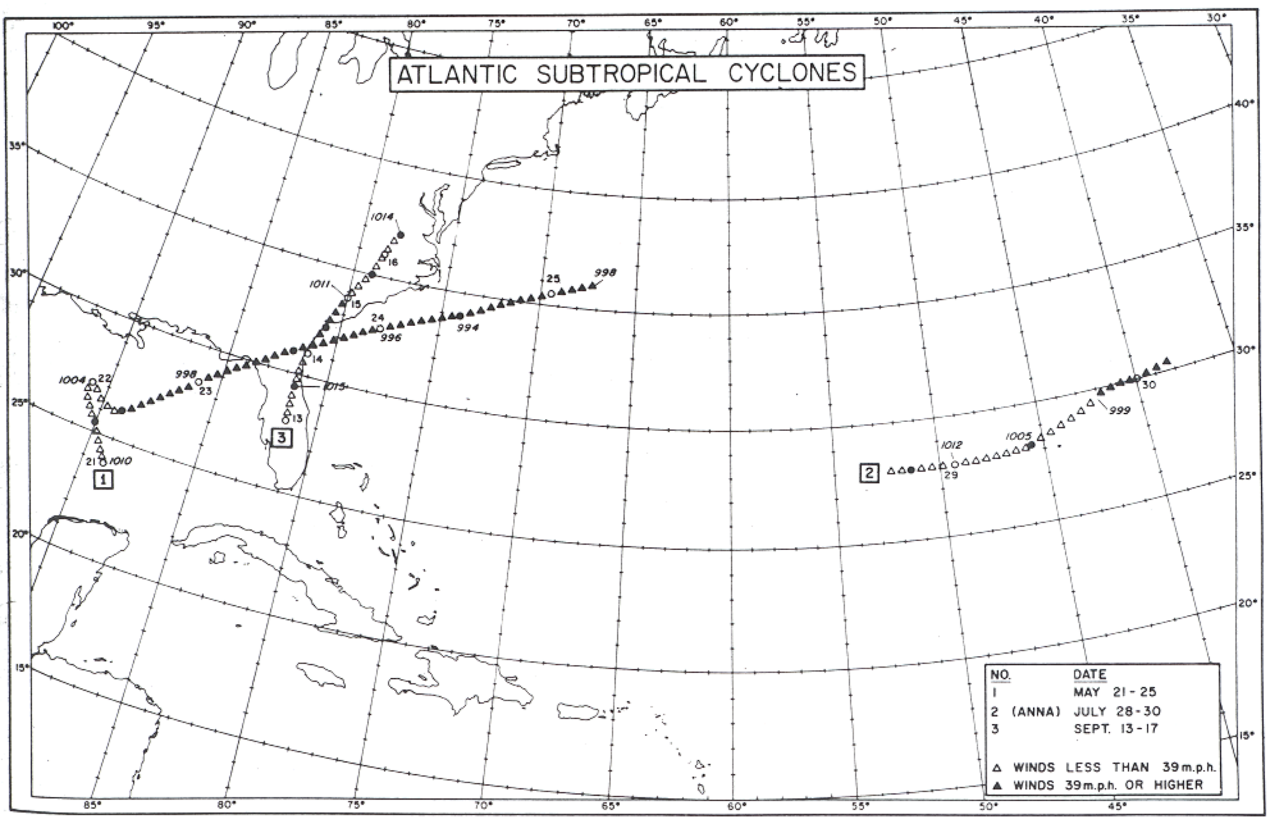


Fig. 2. Tracks of North Atlantic subtropical cyclones, 1976.

TABLE 1. Summary of North Atlantic tropical cyclone statistics, 1976.

No.	Name	Class	Dates	Maximum sustained winds (kt)	Lowest pressure (mb)	U. S. damage ($ million)	Deaths
1	Anna	T	28 July–6 Aug.	40	999		
2	Belle	H	6–10 Aug.	105	957	100	U. S., 5
3	Candice	H	18–24 Aug.	80	964		
4	Dottie	T	17–21 Aug.	45	996	minor	U. S., 4
5	Emmy	H	20 Aug.–4 Sept.	90	974		Azores, 68[1]
6	Frances	H	27 Aug.–7 Sept.	100	963		
7	Gloria	H	26 Sept.–4 Oct.	90	970		
8	Holly	H	22–28 Oct.	65	990		

[1] Deaths caused by plane crash at Lajes during height of storm.

tinued in a northeasterly direction sustaining winds of about 40 kt.

As Anna crossed south of the Azores on 1 August, its path became blocked by a surface ridge to the east and north. The cloud pattern became disorganized and tropical characteristics were lost. After the storm became extratropical, a ship encountered the system 400 n mi northeast of the Azores and at 1200 GMT 2 August, an east wind of 46 kt and a 998.5 mb central pressure were reported. The storm's motion was blocked for the next 3 days as it made a slow counterclockwise loop through the Azores. By now the system was quite weak and passed east of the Azores as a 1015 mb low pressure system on 6 August.

There were no wind reports from the Azores above gale force except after Anna had become extratropical, and there were no reports of damage or casualties.

b. Hurricane Belle, 6–10 August

1) METEOROLOGICAL HISTORY

The precursor of Belle moved westward off of the African Coast on 28 July. It was the 20th tropical system of 1976 to be tracked across the Atlantic and was well defined. On 31 July, in the mid-Atlantic, the system was better organized than most waves seen in this area. Satellite pictures indicated a possible lower-tropospheric circulation and much convection.

The wave traveled across the Atlantic at about 20 kt. While the wave itself continued westward into the Caribbean, the major convection separated just east of the Leeward Islands and moved northwestward and slowed down, reaching a position just east of the northern Bahamas on 5 August.

By this time, the convection was concentrated over a

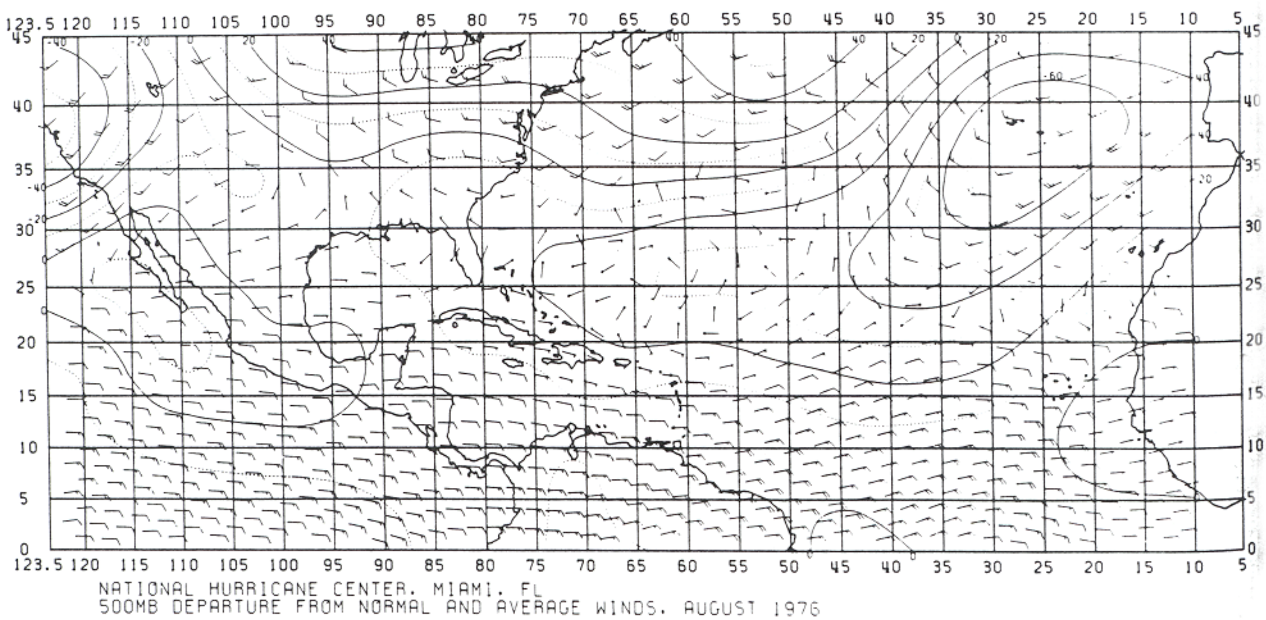


FIG. 3. 500 mb departure from normal of geopotential heights (m) and average winds (kt) for August 1976.

circular area 300–400 n mi wide. And late on 5 August, a well-defined cirrus-level outflow was indicated. Finally, early on 6 August, surface winds reached 25 kt with a minimum central pressure of 1012 mb and the system was upgraded to a tropical depression.

Intensification was rather steady from 6 August to early on 9 August when a central pressure of 957 mb was reached with a maximum sustained surface wind speed of 105 kt. NOAA research aircraft reported spot winds as high as 130 kt, but these winds were measured at or near 700 mb and were not evaluated to be representative of sustained surface winds. Fig. 4 shows a radar picture of Belle at mid-day on 9 August. At this time the central pressure was 963 mb and maximum sustained winds were 95 kt.

As Belle increased in strength, its status was upgraded to tropical storm on the evening of 6 August and to a full hurricane during late afternoon on 7 August. Figs. 5–7 are a series of three satellite pictures, 24 h apart, that shows the evolution of Belle. Fig. 5 shows Belle east of the Bahamas late on 7 August with 985 mb central pressure just after hurricane status was reached. Twenty-four hours later, with the hurricane near 30°N latitude, Fig. 6 shows Belle just prior to maximum intensity with 958 mb. The last of the series (Fig. 7) is for late on 9 August within 12 h of landfall and by this time, Belle was weakening with a central pressure of 970 mb.

As a tropical depression and for the first few hours as a tropical storm, Belle's position remained about 250 n mi east-northeast of Nassau in the Bahamas. Actually during this time there was a small cyclonic looping motion. But soon after reaching tropical storm intensity, acceleration began toward the northwest and toward the north by 8 August. This northward motion continued for the next two days while forward speed increased to 20–25 kt.

Finally, landfall was made early on 10 August (0500 GMT or 0100 EDT) on the south coast of Long Island. The point of landfall is estimated to be in the vicinity of Jones Beach on western Long Island.

The storm moved northward across Long Island, then over Long Island Sound, reaching the Connecticut coast near Bridgeport. Belle's course continued across west central Massachusetts into southwest New Hampshire, finally northeastward into western Maine.

Table 2. Summary of North Atlantic subtropical cyclone statistics, 1976.

No.	Dates	Maximum sustained winds (kt)	Lowest pressure (mb)
1	21–25 May	45	994
2 (Anna)	28–30 July	40	999
3	13–17 Sept.	40	1011

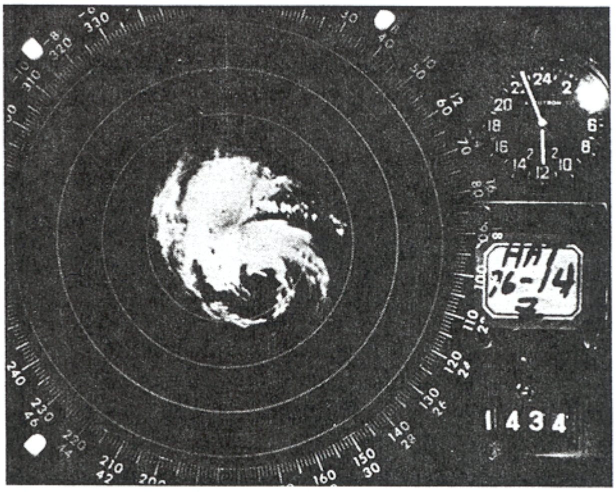


Fig. 4. Radar photograph of Hurricane Belle from Cape Hatteras, N. C., 1157 GMT 9 August 1976.

During this later period, over New Hampshire and Maine, tropical characteristics were lost.

2) Warnings

As is the case with almost every storm that moves very near and parallel to the U. S. east coast, it was necessary to place a hurricane watch and/or warnings over a rather large segment of the Eastern Seaboard.

Belle was no exception. The entire coastline from Georgia northward to Maine was eventually placed under a hurricane watch. Hurricane warnings were first announced for the Outer Banks of North Carolina from Kitty Hawk to Cape Lookout. This was on the afternoon of 8 August when Belle was a little over 300 mi

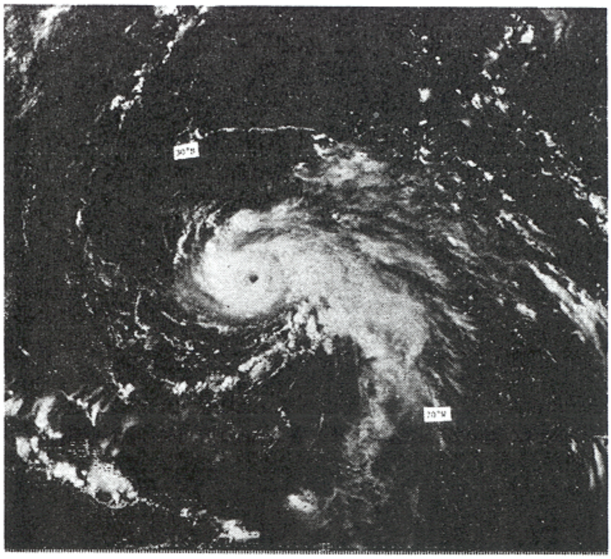


Fig. 5. Visible satellite picture of Belle at 1931 GMT 7 August 1976 (Bahamas and Cuba are in lower left corner of picture) from GOES 1 ($\frac{1}{2}$ n mi resolution).

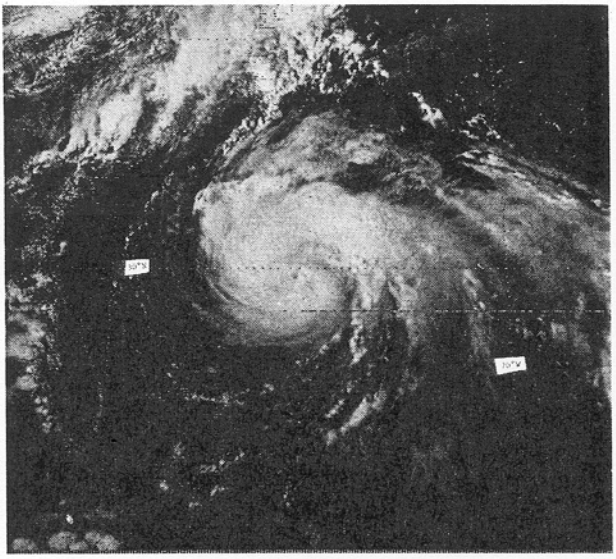


FIG. 6. As in Fig. 5 except for 8 August 1976 (Florida at lower left).

south of Cape Hatteras and moving due northward.

Then on the morning of 9 August, warnings were extended northward to include the remainder of the North Carolina coast and were also placed over much of the northeast area from Delaware northward through Massachusetts. This included the coastal section of New Jersey, New York, Connecticut and Rhode Island. Finally on the evening of 9 August warnings were extended northward from Massachusetts through Maine. By now, Belle had passed to within 100 mi of the North Carolina Outer Banks and warnings were discontinued over this area.

By midday on 9 August, the public advisories started mentioning central or eastern Long Island as the point of landfall. Coastal storm tides of 8 ft or more above normal were emphasized as well as high winds near landfall. An inland flash flood threat was expressed for much of the northeast as heavy rain had already been occurring not associated with Belle. In addition, tides of 12 to 15 ft above normal in some bays and inlets were considered possible near the center.

The basis for this serious threat was the fact that the maximum intensity of the storm, when the warnings were formulated, was in the range of a category 3 storm in the Saffir-Simpson scale which implies extensive damage.[2] It turns out that the storm was on a weakening trend from that time until landfall, a period of almost 24 h. Estimated maximum sustained winds at landfall were 65 kt and minimum sea level pressure was up to near 980 mb. So Belle decreased in intensity from a category 3 major hurricane to a *minimal* hurricane during the 24 h period before landfall.

One of the reasons for this significant weakening before landfall is the fact that Belle's northward motion remained at speeds <25 kt. This allowed more time for the storm to travel over the colder waters of the Atlantic north of the Gulf Stream which veers eastward away from the U. S. coast just north of Cape Hatteras. Most of the major storms that have affected the northeastern United States have accelerated to speeds of motion considerably higher than Belle and therefore did not have as much time as Belle did over colder water.

This is, of course, a fortunate turn of events as far as residents of the warning area are concerned. However, a side effect which is not so fortunate is that many people in the warning area could be lulled into a false sense of security. If these people base their hurricane knowledge only on this single experience, they may become complacent or apathetic about potential dangers of the next hurricane to approach this area.

3) DAMAGE

Estimates of damage caused by strong winds are minimal. Reports indicate that maximum sustained winds were mostly less than hurricane force over most of the warning area. Steady northwest 55–65 kt winds were estimated along the Outer Banks of North Carolina during the period that Belle passed just offshore. Moving northward, the next highest wind reported was 50 kt with gusts to 60 kt at Ocean City, Md. Along the New Jersey coast, 30–40 kt was common but the Bottom estimated 55 kt with gusts to 80 kt, and Manasquan estimated 70 kt gusts.

In the New York City area, LaGuardia Airport measured northeast winds at 52 kt with gusts to 63.

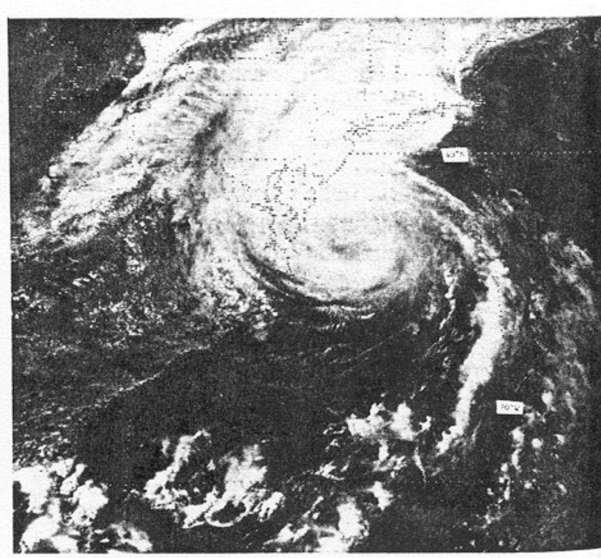


FIG. 7. As in Fig. 5 except for 9 August 1976.

[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.

TABLE 3. Meteorological data of Hurricane Belle, 6–10 August 1976.

Station	Date	Pressure (inches) Low	Pressure Time[a]	Wind (mph) One minute average		Time[a]	Peak gust		Time[a]	Tide (ft) Height above normal	Time[a]	Rainfall (inches) Storm total	Remarks
Data buoy EB15 (32.3°N, 75.3°W)	9	28.38	0100	SW	69	0100							8.5 minute average wind
Data buoy EB41 (38.7°N, 73.6°W)	9	28.90	1800	ESE	57	1800							10 minute average wind
Connecticut													
Bridgeport	10							77	0008				
Hartford	10	29.30	0355	E	30	0140		45	0148			1.58	
New London	9									1.0	2120		
Delaware													
Wilmington	9	29.62	1900	NNW	20	1855	NW	34	2125	2.1	1930	1.05	
Maine													
Portland	10	29.67		S	29	1050	S	43	1004				
Maryland													
Ocean City	9	29.56	1800		58	1700		69	1700	4.0[b]	1700	4.20	
Massachusetts													
Ashfield	10											4.11	
Barrington	10											3.11	
Beckett	10											3.85	
Boston	10	29.63	0715	S	34	0550	S	54	0511	1.4	0400	.01	
Gloucester	10			SE	40	0700							
North Adams	10											4.18	
Scituate	10			SSE	40	0700							
New Hampshire													
Concord	10	29.57	0854					35	0446			.50	
New Jersey													
Atlantic City	9	29.35	2030	NNE	40	1900	NNE	62	1843	8.85[c]	1924	3.00	
Atlantic City Airport	9			NW	29	2158	NW	48	2011			2.75	
Avalon	9	29.95	1730	NW	30[b]	1730	NW	50[b]	1740			3.85	
Beach Haven	9	30.02	1900	NE	45[b]	2200		60[b]	2200			3.73	
Cape May	9	29.47	1915	NW	31		NW	54	2000	2.0		3.86	
Cape May Court House	9			WNW	32	2020	NW	55	2000			3.93	
Manasquan	9						W	80[b]	2030			3.35	
Margate	9											3.9	
Mercer County Airport	9				40			63	2245				
North Wildwood	9			NW	45[b]	1930	NW	55[b]	1930	3.5	1900		
Seaside Heights	9			NE	40[b]		NE	70[b]	2000				
Ship Bottom	9			NE	65[b]			90[b]					
Trenton	9	29.53	2130	NW	38	2227						1.59	
Wildwood Coast	9			NW	30[b]	1700	NW	61[b]	1930				
New York													
Central Park	10			N	28		NW	46	0106			3.98	
Garden City	9	29.16	2355										
Islip	10	29.18	0100										
JFK	9	29.17	2215	NNE	43	2151	NNE	68	2156				
LaGuardia	10	29.24	0015	NE	52	2254	NE	63	2252			3.36	
New York City	10	29.23	0000							4.5			
North Carolina													
Cape Hatteras	9	29.38	0900	NNW	37	0958	NW	63	0917			3.70	
Frisco	9							75[b]					
Hatteras Place	9							75[b]					
Wilmington	9	29.74	0345	NW	16	0803	NW	18	1018				
Pennsylvania													
Philadelphia	9	29.59	2130		30			41	2050			1.23	
Rhode Island													
Block Island	10							74					
Providence	10	29.57	0230	SSE	44	0303	S	60	0448	3.3	0300	1.77	
Virginia													
Norfolk	9	29.68	1300	N	32	1153	N	48	1149	1.9	1330	1.08	
Oceana NAS	9						NW	40					
South Island (Chesapeake Bay Bridge)	9						NW	63					

[a] Eastern Standard Time.
[b] Estimated.
[c] Tide above mean low water.

Sustained winds of 55 kt were common on the south shore of Long Island and an estimated gust to 80 kt was reported from Jones Beach. Finally, as the storm moved across southern New England, there were several instances of gusts to above hurricane force but steady winds were mainly in the 30–40 kt range. Table 3 summarizes the meteorological data associated with Belle.

Tidal variation associated with the storm surge was generally about 3 ft above normal over much of the warning area. However, at some locations from New Jersey southward, tides were somewhat below normal due to an offshore wind component.

Tides of 3 ft over the road surface were observed at points along the North Carolina Outer Banks. At Ocean City, Md., estimates of 4 ft above normal were reported. Battery Park at the south tip of Manhattan had tides of 7.2 ft above mean low water or 4.5 ft above normal. No figures were received from Long Island where it is suspected that some higher tides may have occurred.

Rainfall amounts of 4–5 inches during the 24 h period of Belle's passage were common over much of the warning area as well as quite a distance inland, especially in the western and northern mountains of New England.

Because of widespread precipitation throughout the area for a day or two immediately prior to the hurricane, there was considerable small stream floodings and flooded roads. Crop damage was spotty and although there were some losses to bottomland crops, the New England Crop and Live-Stock Reporting Service said "Damage from Hurricane Belle was much less than anticipated . . .".

In New England, there were three deaths which were attributed to Belle: two drowned in southern Vermont when a foot bridge was swept from under them. In Connecticut, a woman was killed in Barkhamstead when her car skidded into a tree. At Norfolk, Va., a traffic accident due to heavy rain resulted in one death. In New York, a falling tree was responsible for one fatality. Therefore, five storm-related deaths are accounted for.

Reports of dollar damage as well as how many persons evacuated are difficult to estimate. The largest figure available for evacuation is that of 250 000 people along the New Jersey shore. A combined figure of near 30 000 people has been given for New York City and Suffolk County, New York. Connecticut reports approximately 5000 evacuated. Down on the North Carolina coast, 10 000 people evacuated. Unknown thousands were most likely evacuated elsewhere in New England and along the Eastern Seaboard. It can therefore be concluded that nearly half a million people evacuated in anticipation of the danger of Belle's storm surge.

The total damage estimate for the United States is $100 million. This is mainly a result of agricultural crop damage in the northeast United States, although other property damage (dwellings, boats, commercial and beachfront structures) accounts for a considerable percentage. This figure is based primarily on data provided by the Property Claim Services of the American Insurance Association.

c. Hurricane Candice, 18–24 August

Candice originated as a baroclinic system. As early as 11 August, a cold low was clearly evident at 200 mb, centered about 500 n mi southeast of Bermuda. At this time there was no reflection of the system on the surface pressure analysis; in fact, a surface ridge of high pressure extended north–south along 60°W longitude. The outline of the cold low was clearly seen on a movie loop made from successive satellite pictures.

This upper low drifted northwestward for the next few days and convective cloudiness increased, but it was not until 16 August that a broad low pressure area was detected on surface charts. Meanwhile, the low at 200 mb was becoming less well defined; by 17 August only an upper trough west of the surface low could be identified and the flow above the surface low became increasingly anticyclonic. This suggested a general warming of the system and a transformation to tropical structure.

At 1200 GMT 18 August, about 200 n mi west of Bermuda, the low was classified as a tropical depression as satellite pictures showed increasingly better organization and a ship reported winds gusting to 40 kt. Development continued and it was named later on the same day.

As the storm moved northeastward about 15 kt, slight weakening occurred beginning on the afternoon of 19 August and continuing until the following afternoon, when the storm again began to deepen. It became a hurricane during the night of 20 August. Maximum intensity was reached on the afternoon of 22 August when the lowest pressure dropped to 964 mb and maximum sustained winds were 80 kt.

Early on 24 August, the hurricane was overtaken by a rapidly moving cold front east of Cape Race, Newfoundland. It rapidly lost its identity as a tropical system while accelerating northeastward over the open Atlantic.

Candice initially took a north-northeast course around the periphery of a 1031 mb high centered just west of the Azores. By 21 August the central pressure of the high had dropped to 1026 mb and as steering currents became balanced, the hurricane drifted southeastward for about 24 h. It began to be influenced by a prefrontal trough on 22 August, after which it accelerated northeastward.

There were no known casualties or damages associated with Candice.

d. Tropical Storm Dottie, 17–21 August

Dottie began spectacularly and ended ignominiously. The initial low center which became Dottie formed about 150 n mi northwest of Key West during the evening of 17 August in response to a strong upper level trough which moved rapidly southward into the eastern Gulf of Mexico. On the next morning the center consolidated between Dry Tortugas and Key West as pressures fell 8 mb in 24 h in the area. The depression drifted slowly east and northeast during the next 24 h with the pressure falling to 1004 mb at Key West during the early morning hours of 19 August.

The system moved northeast rapidly during the morning and was named Dottie that afternoon as it reached the Atlantic near Palm Beach. The depression was not upgraded to a storm in the morning because of the uncertainty that the center might remain over land. However, post-analysis indicates storm strength was attained by 1200 GMT. Air Force reconnaissance reports indicated 35 kt winds near the middle Keys around mid-morning and 35–45 kt gusts were reported in the middle and upper Keys and on Grand Bahama during the day. In addition, 24 h rainfall amounts of 5 inches were common in the Greater Miami area with one report of over 8 inches in Coral Gables.

Building high pressure north of the storm indicated Dottie would turn more to the west. Also, conditions appeared favorable for further strengthening. Accordingly, gale warnings were issued at 2200 GMT 19 August from Jacksonville, Fla., to Virginia Beach, including Pamlico and Albemarle Sounds, and a hurricane watch from Savannah, Ga., to Cape Hatteras, N. C. The hurricane watch was extended to Jacksonville at 1000 GMT the next morning when it appeared the center was slowing and turning more to the west. However, the storm continued north and moved inland near Charleston, S. C., during the evening.

Dottie strengthened after moving off the Florida coast and an Air Force plane found the storm's minimum central pressure of 996 mb and maximum estimated surface winds of 45 kt around 0600 GMT 19 August when the center was about 75 mi northeast of Daytona Beach. Strong high-level winds over the storm caused weakening threreafter and Dottie was barely of tropical storm strength at land fall.

Gusts of 35–40 kt were reported at beach locations near Wilmington, N. C. Tides were 3.5 ft above normal at Atlanta Beach, N. C., and ranged from 1–2 ft above normal from Jacksonville Beach to the North Carolina Outer Banks. Carolina Beach had a storm rainfall of 7.78 inches with amounts of 4–6 inches over the remainder of coastal North Carolina near Wilmington.

The low pressure center which was the remnant of Dottie moved back over the water on 22 August. It almost retraced the storm track, south and then southwest across central Florida into the Gulf of Mexico where it lost its identity on 25 August. No strong winds or significant shower activity were associated with the low and it has not been included in the track.

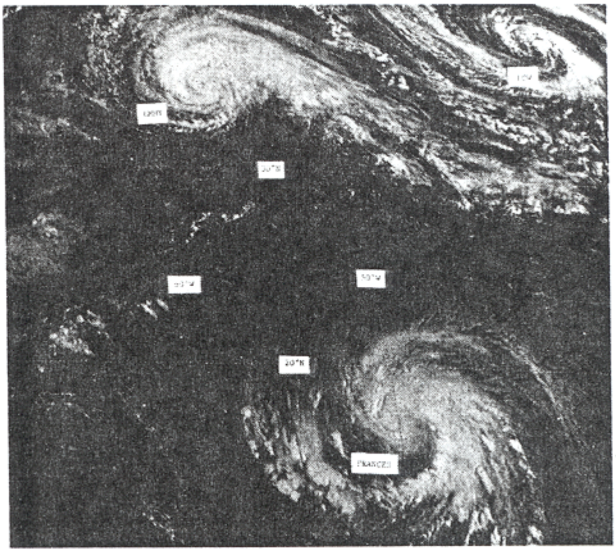


FIG. 8. Visible satellite picture at 1131 GMT 29 August 76, from GOES 1 (1 n mi resolution). Area is central North Atlantic showing Emmy (upper left), Frances (bottom) and extratropical low-pressure system (upper right).

Four deaths resulted from Dottie when a fishing boat went down on 19 August near Grand Bahama Bank. Damage from the storm was minor, occurring mainly as beach erosion from Georgia to North Carolina.

e. Hurricane Emmy, 20 August–4 September

A tropical disturbance moved off the African coast on 15 August. After traveling westward at 15–20 kt for several days, a depression formed 1000 n mi east of the Lesser Antilles on 20 August. This depression gradually strengthened as it slowed to 10 kt and became Tropical Storm Emmy on 22 August at a position 300 n mi east of the Leeward Islands.

Emmy was now moving northwest about 15 kt and by late on 24 August, recurvature began. Emmy had reached hurricane force on 25 August and was heading eastward, an unprecedented course for the time of year at this low latitude. The rapid development of an unseasonal low pressure system in the mid-Atlantic northeast of Emmy was responsible for the early recurvature. Large-scale circulation features concerning this recurvature are discussed in Section 1.

Emmy resumed a north to northwest course from 26 to 28 August encountering strong upper level westerlies and again turning to the east on 29 August. The hurricane maintained an easterly direction for the next several days. On 2 September, Emmy turned northward, crossing the central Azores. Weakening commenced as Hurricane Frances approached and Emmy was finally absorbed by the large circulation of Frances on 4 September.

The storm's highest intensity was reached on 29 August when a reconnaissance aircraft reported a wind of 90 kt and a central pressure of 974 mb. Fig. 8 shows a satellite picture of Emmy near maximum strength on 29 August. Frances and a cutoff low near the Azores can be seen as well.

Several ships were buffeted by the high seas and winds of Emmy, but there were no reports of significant damage. A Venezuelan Air Force plane carrying a school choir to Europe crashed while attempting to land at Lajes Air Force Base in the Azores while the storm was in progress and 68 people were killed.

f. Hurricane Frances, 27 August–7 September

Frances followed an unusual track through the central Atlantic, similar to the path of Emmy, with which it coexisted for 6 days.

A tropical wave crossed the African coast on 24 August and became a depression 3 days later as it moved westward in the trade wind belt. The first reconnaissance flight into the system found winds of 50 kt and a minimum pressure of 1002 mb on 28 August, at which time the new storm was designated Frances.

Early on 28 August Frances crossed about 1000 n mi to the south of Hurricane Emmy, near longitude 53°W. Shortly thereafter the storm took a northwestward turn into the weakness in the Bermuda-Azores high left by Emmy.

The storm became a hurricane on 30 August and reached its maximum intensity on 1 September, when winds of 100 kt were measured by reconnaissance aircraft along with a minimum pressure of 963 mb.

Frances continued to follow in the trough left by Emmy, and turned toward the east during 1 September. This hurricane recurved south of latitude 30°N, which except for Emmy's first eastward turn was unprecedented for that time of year. At that time, the two hurricanes, together with a low near the Azores and a frontal trough to the northwest, produced an enormous area of negative surface pressure anomalies stretching from Europe westward through the Azores to Bermuda, and from the Virgin Islands to Newfoundland.

As Frances turned toward the east and then northeast toward the Azores, it gradually weakened. Satellite pictures suggest that it had lost tropical characteristics by the morning of 4 September. The extratropical stage of the storm passed through the eastern Azores on the next day. Then the remaining low pressure center made a counterclockwise loop to the north of the Azores. For several days after that, the residual weak circulation in the cloud pattern could be tracked as it moved southwestward, parallel to, and a short distance south of the earlier track of Frances.

No reports of damage or casualties caused by Frances were received.

g. Hurricane Gloria, 26 September–4 October

Gloria originated as a tropical wave which moved westward off of the African coast on 18 September. This wave traveled toward the west-northwest at 10 kt, reaching a location approximately 400 n mi northeast of the Leeward Islands of the Caribbean on 26 September. While this was occurring, an upper-tropospheric cold low moved toward the southwest from a position in the central Atlantic midway between the Leeward Islands and the Azores.

On 23 September, the upper low came close enough to the wave so that the cloud features, which were now enhanced by the combining synoptic systems, started to show signs of becoming better organized. On 26 September, the low-level circulation became sufficiently well defined to locate a tropical depression 400 n mi northeast of the Leeward Islands.

The depression moved northward to northwestward at less than 10 kt for a few days while gradually intensifying. It became Tropical Storm Gloria at 1200 GMT on 27 September and a hurricane at 0600 GMT two days later.

At the time Gloria reached hurricane intensity, the storm was located about 300 n mi southeast of Bermuda and heading in a northwesterly direction. This was the only time that there was a threat to any land area and this was not considered to be a serious problem as the storm was forecast to turn back to the north and then northeast before coming very close to Bermuda.

During this time a series of short-wave troughs in the westerlies were moving across the Canadian Maritime Provinces and out over the North Atlantic. So as Gloria moved farther north, it became increasingly more likely that it would recurve toward the northeast. This finally occurred early on 30 September and the hurricane moved eastward to northeastward for the next several days while gradually weakening.

Maximum winds decreased to tropical storm strength on 2 October while Gloria was centered about 600 n mi south of Cape Race, Newfoundland. Two days later, Gloria weakened to a depression and became extratropical on 5 October just north of the Azores.

No damage or deaths are known to have been caused by Gloria. Maximum sustained surface winds are estimated to have been 90 kt and the minimum sea level pressure was 970 mb. These figures are based on aircraft reconnaissance and satellite imagery.

h. Hurricane Holly, 22–28 October

A relatively weak wave moved off the coast of Africa into the Atlantic on 14 October. Six days later, satellite pictures revealed that the cloudiness associated with this wave had become rather concentrated at a location 700 n mi east of the Leeward Islands. Organization continued and late on 22 October the system reached depression stage. Now moving northwestward, the depression intensified to storm strength on 23 October and to a minimal hurricane on the following day near latitude 25°N, longitude 58°W. This intensity was maintained for only 24 h, after which it dropped back to tropical storm status. This status continued until the storm lost its identity as it merged with a strong cold front over the North Atlantic on 28 October.

Upper air conditions were not considered particularly favorable for tropical development when the system first reached the depression stage on 22 October. At 200 mb the flow was generally cyclonic over the developing storm as an upper low was located just to the north of the depression. By the time Holly became a hurricane, however, the upper low had opened into a trough lying some 5° to the west of the hurricane's position. This configuration resulted in anticyclonic flow over the storm at 200 mb.

As the hurricane moved northeastward, the higher latitude portion of the upper trough moved eastward rapidly enough to overtake the storm. This interaction resulted in weakening of the storm and some loss of tropical structure even before it merged with the cold front.

Holly's lowest pressure was 990 mb on 24 October, and the highest wind reported by reconnaissance aircraft was 65 kt on the same day.

3. Subtropical storms

a. Subtropical storm no. 1, 21–25 May

Widespread cloudiness and showers were indicated by satellite pictures over most of the Gulf of Mexico and northwest Caribbean on 19 and 20 May. These unsettled conditions were produced by the interaction of an upper level trough moving slowly eastward with a weakening stationary front extending from central Florida into the western Gulf of Mexico.

On 21 May, reports from the NOAA Buoy EB04 (26°N, 90°W) and ship observations indicated a low-pressure system was developing over the central Gulf of Mexico. The low gained strength and drifted northwest until becoming nearly stationary on 22 May just north of EB04.

A developing trough in the westerlies over the Mississippi Valley began to influence the low on 23 May and the system strengthened to subtropical storm intensity. The storm accelerated toward the east-northeast at 20 kt and crossed north Florida and southwest Georgia that afternoon. The system continued into the Atlantic and merged with a frontal system by 25 May.

The development of the storm had some characteristics of a tropical system while in the Gulf of Mexico, but the environment remained cold and the approach of an upper trough prevented any further warming of the system. However, the upper trough did contribute to the strengthening of the low and a lowest pressure of 994 mb was estimated on 24 May when the storm was offshore of the Carolinas. Highest winds were 45 kt.

Tides of 1–2 ft above normal occurred along the Gulf coast from Tampa to Pensacola, and combined with large swells, caused beach erosion in this area. Heavy rainfall was reported over eastern South Carolina with 5 inches at Charleston. Damage from the storm was minimal and rainfall was beneficial to the southeastern states since precipitation had been below normal in this area.

b. Subtropical storm no. 2, 28–30 July

(See discussion on Tropical Storm Anna.)

c. Subtropical storm no. 3, 13–17 September

On 12 September, the interaction between a mid-tropospheric low and a diffuse stationary front caused the formation of a surface low pressure system over central Florida. This low moved northward and developed into a subtropical storm late on 13 September as the center moved offshore just north of Jacksonville, Fla. After only a short overwater trajectory the storm crossed the coast just below Charleston, S. C., on 14 September. The system, now weakening overland, moved north-northeast through the mid-Atlantic states, finally dissipating over Virginia on 17 September.

A large high pressure system located over the mid-Atlantic states, north of the low, produced a strong pressure gradient which caused gale force winds off the Georgia and Carolina coasts during the passage of the storm. Charleston reported gusts to near 50 kt in the downtown area shortly before the storm center reached the coast. Heavy rains accompanied the storm over eastern Georgia, South Carolina and southeastern North Carolina. Most reporting stations in those areas reported between 3 and 6 inches. Tides were 2–3 ft above normal along the Carolina coasts. Damage was mainly confined to minor beach erosion and local stream flooding.

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 and D. Senn prepared the graphics. L. Wilson typed the manuscript.

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.

Dickson, R. R., 1976: Weather and circulation of August 1976. *Mon. Wea. Rev.*, **104**, 1455–1460.

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

Hope, J. R. 1975: Atlantic hurricane season of 1974. *Mon. Wea. Rev.* **102**, 285–293.

Wagner, A. J., 1977: Weather and circulation of October 1976. *Mon. Wea. Rev.*, **105**, 123–129.

Atlantic Tropical Systems of 1976

NEIL L. FRANK AND GILBERT CLARK

National Hurricane Center, National Weather Service, NOAA, Miami, Fla. 33124

ABSTRACT

The 1976 hurricane season produced 111 "tropical systems," of which 23 acquired the closed circulation of a depression. Over half of these (68) originated over the African Continent. These are the most African systems observed since our annual summary began in 1968. African seedlings initiated four of the eight named Atlantic storms, and all but one of the fourteen East Pacific storms.

1. Introduction

This is the ninth 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).

Last year Hebert (1976) speculated the tropics may be returning to normal, and this trend continued this past summer. For example, Lawrence (1977) found that mid-season sea temperatures were near normal over the breeding grounds of Atlantic hurricanes. The vertical shear of the horizontal wind was also generally less over the tropics than observed for the past four years. However, even though several factors pointed toward a normalcy, including the number of named storms, there were some highly anomalous features that produced a very unusual season.

Lawrence (1977) noted the following unique events:

1) This was only the second time this century there were no named storms in the Caribbean or Gulf of Mexico.

2) Emmy and Frances both recurved toward the east at very low latitudes. This was a response to the development of a large baroclinic cyclone north of Emmy that moved eastward and became quasi-stationary over the Azores. The combination of this cyclone with Emmy and Frances produced extremely low negative anomalies in the height pattern over the central Atlantic that persisted from late August to mid-September.

In addition, negative height anomalies off the west coast of California in September and October caused the recurvature of three hurricanes and one tropical storm onto the west coast of Mexico.

Meteorologically, the 1976 hurricane season might properly be designated as the "summer without a September." The onset of an early winter with strong cold fronts sweeping southeastward from the United States and penetrating deep into the tropics in late September and October abruptly ended the threat of a serious U. S. hurricane. Once again there was an absence of a classical September super-hurricane that is typically initiated by an African disturbance over the tropical Atlantic east of the Antilles.

2. Census of 1976 tropical systems

The systems observed during the 1976 hurricane season are given in Table 1, and results for several categories are summarized in Table 2 and Fig. 1. Table 1 describes the history of the 111 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 latitude 20°N. The Atlantic and Eastern Pacific storms that were initiated by Atlantic seedlings are listed in the last four columns.

Table 2 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, Emmy, Frances and eight depressions that formed in the tropical Atlantic south of latitude 20°N were initiated by African waves. Once again we see that nearly half of 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

TABLE 1. Summary of the tropical systems of 1976.*

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 depression	Pacific storm
		5/1		May 5	ITCZ	5/6									
							5/6	May 7	ITCZ						
								May 12	ITCZ						
		5/3		May 8	ITCZ										
		5/8	5/10												
								May 18	Wave						
		5/9		May 15	Wave										
										5/21		STC A			
														# 1	
								May 22	Wave						
		5/12		May 18	Wave										
		5/13	5/15												
				May 23	Wave	5/23									
May 15	Wave														
							5/25	May 26	ITCZ						
				May 25	Wave	5/27								# 2	Annette
		5/21													
								May 30	Wave						
				May 27	Wave										
May 19	Wave														
								June 2	Wave						
				May 30	Wave										
		5/27													
								June 6	Wave						
				June 2	Wave										
May 26	Wave														
								June 9	Wave						
				June 4	Wave										
May 29	Wave														
June 1	Wave		6/3								6/7	# 2			
										6/11		# 3			
								June 14	Wave						
				June 10	Wave										
June 3	Wave														
								June 16	Wave						
				June 12	Wave									# 3	Bonny
June 6	Wave														
								June 18	Wave						
				June 14	Wave										
June 8	Wave														
		6/12	6/15											# 4	
								June 25	Wave						
				June 22	Wave										
June 14	Wave														
			6/19												
June 17	Wave														
								June 28	Wave						
				June 25	Wave										
		6/24													
				June 26	Wave	6/27									
June 21	Wave														
								July 2	Wave						
				June 28	Wave										
June 23	Wave														
								July 4	Wave						
				July 1	Wave										
June 26	Wave														
								July 7	Wave						
				July 4	Wave									# 5	Celeste
June 28	Wave														
								July 8	Wave						
				July 5	Wave										
June 29	Wave										7/6	# 4			
								July 10	Wave						
				July 7	Wave										
July 2	Wave														
				July 8	Wave	7/9								# 6	Diane
		7/7													
								July 12	Wave						
				July 9	Wave										
July 5	Wave														
				July 11	Wave	7/12								# 8	Fernanda
		7/8													
								July 16	Wave						
				July 13	Wave									# 7	Estelle
July 7															
							7/17	July 18	ITCZ						

* Dep. indicates depression.

TABLE 1 (*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 depression	Pacific storm
July 11	Wave			July 17	Wave			July 21	Wave						
											7/20	# 5			
July 13	Wave			July 20	Wave			July 23	Wave						
		7/21		July 23	Wave			July 26	Wave						
July 17	Wave			July 24	Wave			July 27	Wave					#11	
July 20	Wave			July 27	Wave			July 30	Wave					# 9	Gwen
		7/26		July 28	ITCZ			Aug. 1	ITCZ						
July 22	Wave			July 29	Wave			Aug. 2	Wave			# 6		#10	Hyacinth
July 24	Wave			July 30	Wave			Aug. 3	Wave						
											7/29	STC B	Anna		
July 26	Wave			Aug. 2	Wave			Aug. 5	Wave			# 8	Belle		
July 29	Wave			Aug. 4	Wave			Aug. 8	Wave					#12	
July 31	Wave			Aug. 7	Wave			Aug. 11	Wave						
Aug. 2	ITCZ		8/3												
Aug. 3	Wave			Aug. 9	Wave			Aug. 12	Wave						
							8/14	Aug. 15	ITCZ						
		8/12		Aug. 13	Wave			Aug. 17	Wave						
Aug. 7	Wave			Aug. 14	Wave			Aug. 18	Wave						
											8/18	# 9	Candice		
										8/18		#10	Dottie		
Aug. 10	Wave			Aug. 16	Wave			Aug. 20	Wave						
Aug. 13	Wave			Aug. 19	Wave			Aug. 21	Wave					#13	Iva
Aug. 16	Wave			Aug. 23	Storm			Aug. 27	Wave			#11	Emmy	#14	Joanne
Aug. 18	Wave			Aug. 25	Wave			Aug. 29	Wave						
Aug. 20	Wave			Aug. 26	Wave			Aug. 30	Wave						
Aug. 22	Wave			Aug. 27	Wave	8/28									
Aug. 23	Wave			Aug. 29	Wave			Sep. 2	Wave					#15	Kathleen
Aug. 25	Wave			Aug. 30	Storm	8/31						#12	Frances		
Aug. 28	ITCZ			Sep. 3	Wave			Sep. 6	Wave						
Aug. 30	Wave		8/31												
											9/4	#13			
										9/5		#14			
		9/3		Sep. 5	Wave			Sep. 9	Wave						
Sep. 1	Wave			Sep. 7	Wave			Sep. 10	Wave						
							9/10	Sep. 13	ITCZ						
										9/13		STC C			
Sep. 4	Wave			Sep. 10	Wave			Sep. 14	Wave						
		9/5	9/8												

TABLE 1 (*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 depression	Pacific storm
Sep. 8	Wave			Sep. 14	Wave			Sep. 18	Wave					#16	Liza
Sep. 10	ITCZ			Sep. 18	Wave			Sep. 21	Wave	9/22		#17			
Sep. 13	ITCZ			Sep. 20	Wave			Sep. 23	Wave						
Sep. 15	Wave		9/16											#17	Madeline
Sep. 16	Wave			Sep. 22	Wave			Sep. 26	Wave			#19	Gloria		
		9/24		Sep. 25	Storm			Sep. 29	Wave						
Sep. 19	Wave			Sep. 28	Wave			Oct. 3	Wave			#16			
		9/22	9/25												
Sep. 24	Wave			Oct. 1	Wave			Oct. 6	Wave						
Sep. 25	Wave		9/28												
Sep. 27	Wave			Oct. 5	Wave			Oct. 8	Wave			#20			
Sep. 29	Wave			Oct. 7	Dep.	9/12									
							10/11	Oct. 13	ITCZ					#18	Naomi
Oct. 2	ITCZ			Oct. 10	Wave			Oct. 15	Wave						
Oct. 3	Wave		10/5									#21			
Oct. 5	Wave		10/15												
Oct. 10	Wave			Oct. 17	Wave			Oct. 22	Wave						
		10/15		Oct. 20	Wave			Oct. 26	Wave			#22	Holly		
Oct. 13	Wave			Oct. 23	Storm	10/24									
Oct. 16	Wave			Oct. 27	Wave	10/29									
Oct. 19	Wave			Oct. 29	Wave	10/31									
Oct. 21	Wave		10/23								10/31	#23			
							11/4	Nov. 5	Wave						
Oct. 26	Wave			Nov. 4	Wave			Nov. 9	Wave						
Oct. 29	Wave		11/3												
		11/6		Nov. 8	ITCZ			Nov. 12	ITCZ						
Nov. 6	Wave			Nov. 12	Wave			Nov. 16	Wave						
							11/18	Nov. 18	ITCZ						
		11/13		Nov. 17	Wave	11/18									
Nov. 12	ITCZ			Nov. 21	ITCZ			Nov. 25	Wave						
Nov. 16	Wave			Nov. 24	Wave	11/25									
Nov. 18	Wave		11/19												
Nov. 20	Wave		11/23												
Nov. 25	Wave		11/30												

TABLE 2. Summary of 1976 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	Carib-bean	Gulf of Mexico	Total
Waves	62	13	0	1	0	76
ITCZ	6	9	0	7	0	22
Depression	0	(8)	7 (1)	0	6	13 (9)
Named storms	0	(2)	(5)	0	(1)	(8)
Subtropical storms	0	0	(1)	0	(2)	(3)
	68	22 (10)	7 (7)	8	6 (3)	111 (20)

has been used as a dividing line. Of the 68 African systems, 55 were tracked to the Caribbean and 45 all the way to the Pacific Ocean. Over the tropical Atlantic, 22 disturbances formed with 17 eventually passing through the Antilles. Another five were identified along the ITCZ and followed for at least 48 h before dissipating. A total of 72 systems crossed the Antilles (55 from Africa plus 17 that formed in the Atlantic) of which 58 maintained their identity while traversing the Caribbean. The eight disturbances that formed over the Caribbean added to the number from the Antilles resulted in 66 seedlings entering Central America.

One unusual aspect of the 1976 season was the early appearance of a well-defined African wave that moved by Dakar on 15 May. The first African system of the season does not generally occur until late May or early June when the easterly subtropical jet becomes established across tropical Africa in the upper troposphere.

The depression tracks for the months May through October are shown in Fig. 2. The first depression of the season developed in May along an old baroclinic zone in the Gulf of Mexico. This system strengthened and was designated a subtropical storm on the 23rd. Lawrence (1977) describes the history of this storm. The last depression of the year formed on an old front northeast of Puerto Rico on 31 October, and persisted 4 days before weakening.

Most of the depressions in 1976 formed along the lower tropospheric baroclinic zones over the subtropical Atlantic, and did not threaten the United States. Only two reached the U. S. coast and neither offered a serious problem. Both formed over the Northern Gulf of Mexico and approached the Gulf states in September.

Apart from the depressions that strengthened into named storms, only one other was noteworthy enough to warrant special comment. The depression that was spawned by an African wave in the central Atlantic on 3 October caused some concern in the Antilles. Fortunately, strengthening never occurred, and the system moved through the Islands with a very weak circulation. The depression turned toward the north in the central Caribbean and weakened over Hispaniola. Heavy rains were reported over parts of Hispaniola, but there were no reports of serious flooding or damage.

Fig. 3 summarizes the source of Eastern Pacific named storms. All but one of the storms were initiated by African disturbances. This is the most Pacific storms initiated by African disturbances since we began keeping records in 1968. African systems certainly controlled hurricane activity in the Eastern Pacific in 1976.

3. Comparison with other years

Table 3 compares the tropical systems in 1976 with averages determined over the previous eight years within several categories. The totals in most categories in 1976 were slightly higher than the previous eight-year average but compared very closely with the numbers in 1975.

Frank (1974) introduced a simple parameter that seems to be useful in describing the overall character of the hurricane season. This is computed by forming the

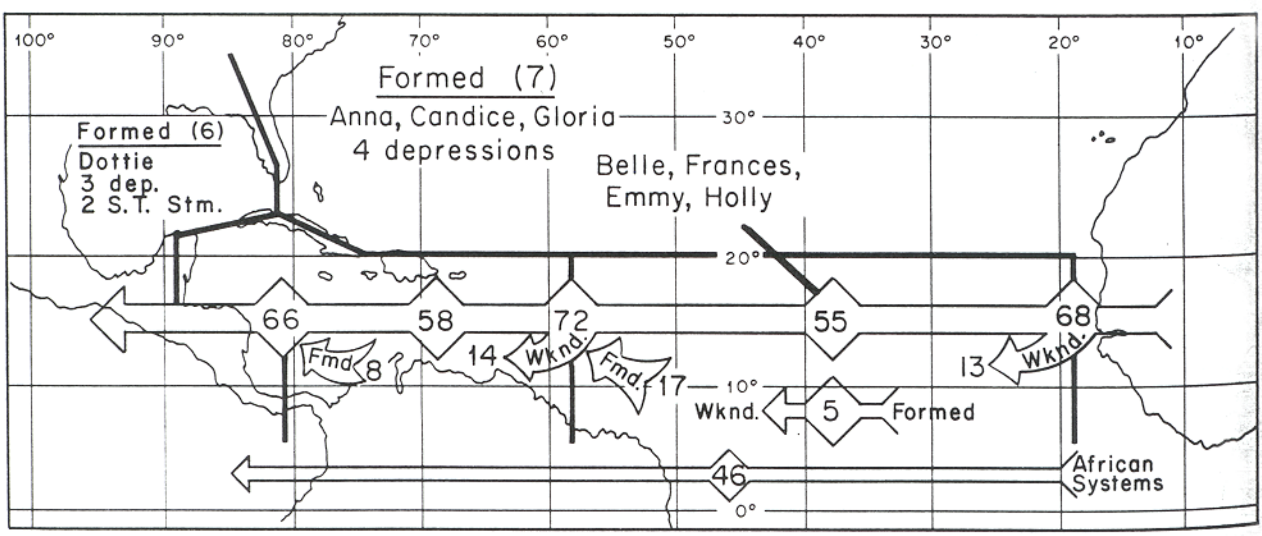


FIG. 1. Summary of tropical disturbances that passed three key stations (Dakar, Barbados, San Andres) in 1976 and those maintaining their identity while crossing the Atlantic and Caribbean.

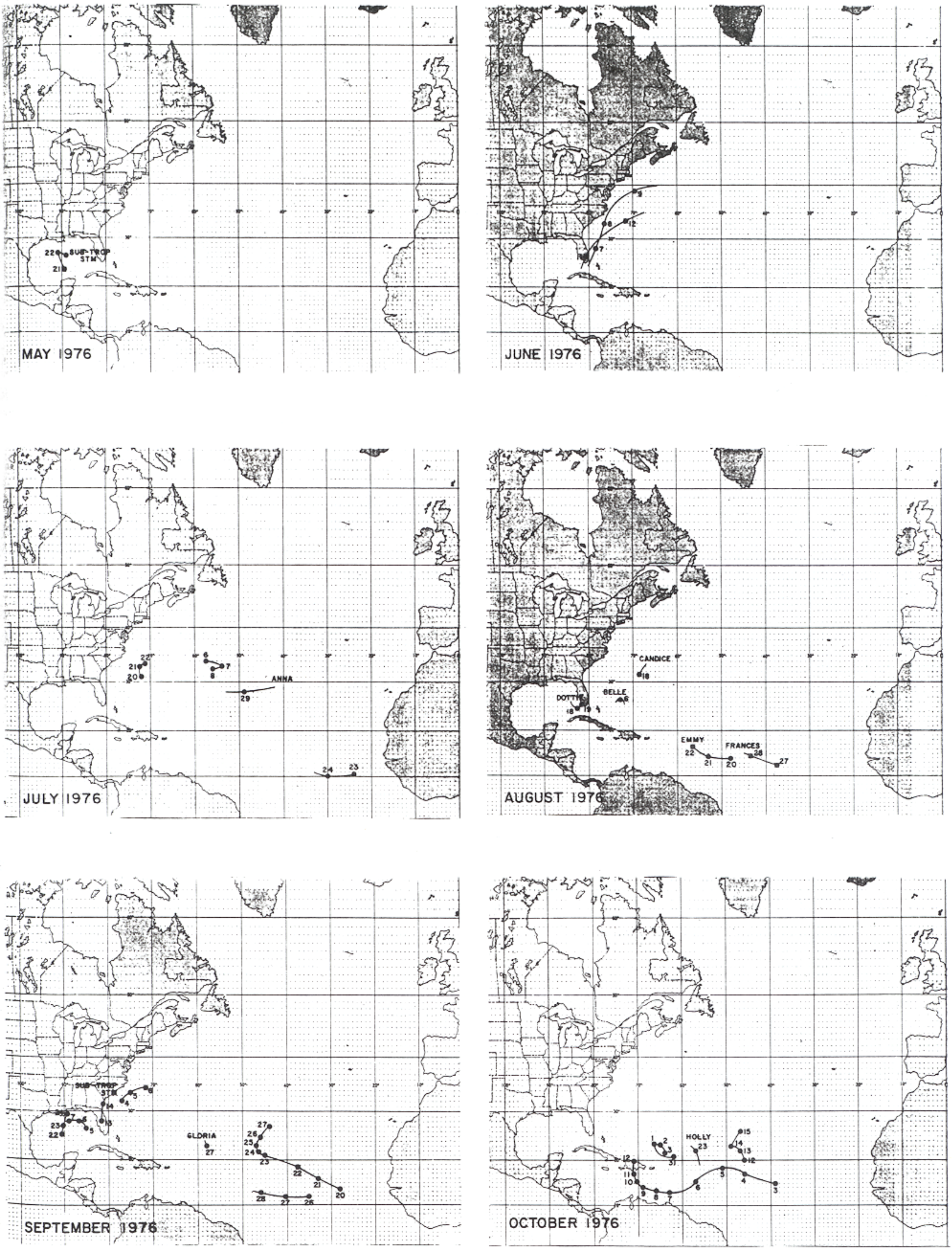


FIG. 2. Tracks of 1976 depressions.

TABLE 3. Results of 1976 compared with the previous eight years.

	1968	1969	1970	1971	1972	1973	1974	1975	8-year average	1976
Total systems (All types)	107	105	85	103	113	95	96	113	102	111
Dakar systems	57	58	54	56	57	56	52	61	56	68
Barbados systems	59	44	53	56	56	58	58	69	57	72
San Andres systems	40	43	45	58	49	54	52	64	51	66
Depressions*	22	34	26	23	24	24	25	28	26	23
Named storms	7	13	7	12	4	7	7	8	8	8
Subtropical storms					4	1	4	2		3

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

ratio of the number of depressions of tropical origin to the total number of depressions. The 1976 value has been added to Fig. 4, and we observed a continuation of the regime that has persisted for the past five years. Low values of this ratio indicate a high number of baroclinic depressions and we have observed this to be associated with anomalous baroclinic conditions over the tropics.

The story of the 1976 hurricane season is well summarized in Table 4, in which we see that over half of the depressions (12) were initiated by baroclinic seedlings. In the table, the 1976 results can be compared with the averages for the past nine years; however, a more meaningful comparison can be made by dividing the past nine years into two periods. The years from 1967 to 1970 were characterized by normal storm activity, while a quiet period has been observed during the period 1971 to 1975. Even though there is little difference in the total number of depressions, there is a very significant difference in the character of the disturbances that initiated the depressions. During the four-year normal period, two-thirds to three-fourths of the depressions were spawned by tropical-type seedlings, and subtropical cyclones were not very common. But during the last five years over half of the depressions were initiated by baroclinic disturbances, and subtropical cyclones/subtropical storms were much more frequent. The character of a hurricane season is directly related to the amount of activity in the subtropical latitudes.

Another perspective of the season is shown in Table 5 which compares the monthly incidents of depressions with the past nine-year averages. From this table one might conclude 1976 was a very normal year because the numbers each month are very close to the longer period averages. However, as we have already seen, the nature of a hurricane season depends upon the character of the depressions and named storms as well as the total numbers.

In the final analysis, one must conclude the 1976 hurricane season was quieter than normal and the lull in both the number and severity of hurricanes, currently being enjoyed by interests in the Atlantic, has now persisted for six years.

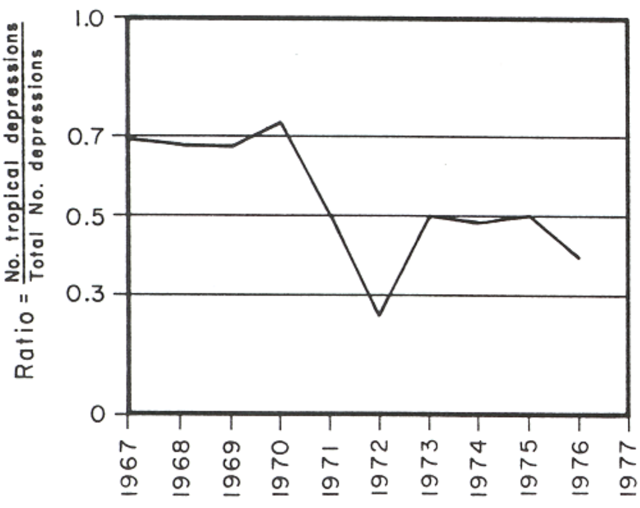


FIG. 3. Summary of the type of seedlings that initiated east Pacific storms in 1976.

TABLE 4. Summary of the type of seedling that initiated Atlantic named storms and depressions during 1976 compared with annual averages from previous years.

Year	Tropical: African systems	Tropical: Disturbances	Baroclinic: Upper troposphere	Baroclinic: Lower troposphere	Totals
Named storms					
1976	4	0	3	1	8
Average 1967–75	4.0	2.0	1.0	1.0	8.0
Average 1967–70	4.0	3.0	1.0	1.0	9.0
Average 1971–75	4.0	1.0	1.0	2.0	8.0
Depressions*					
1976	10	0	3	9	22
Average 1967–75	10.0	4.0	4.0	6.0	24.0
Average 1967–70	13.0	5.0	3.0	4.0	25.0
Average 1971–75	8.0	3.0	4.0	8.0	23.0

* Only the depressions that occurred from June through November.

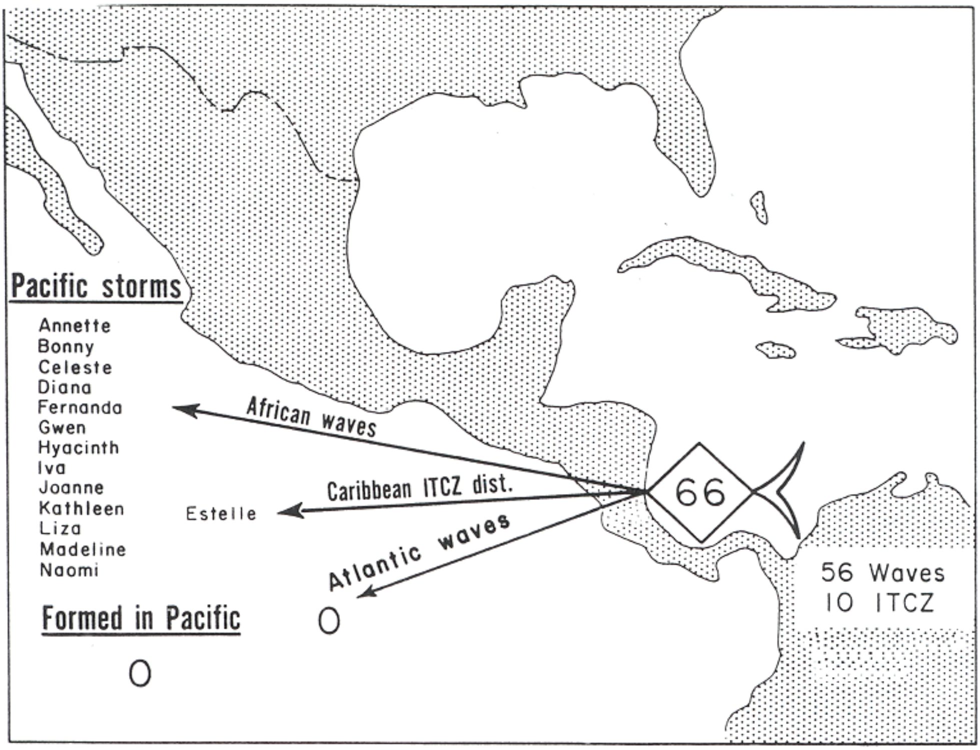


Fig. 4. Ratio of the number of depressions of tropical origin to the total number of depressions, 1967–76.

Table 5. Number of depressions that formed each month compared with monthly averages determined over the 9-year period 1967 through 1975.

	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1976	0	1	2	4	5	7	4	0	0	23
Average 1967–75	1.0	1.0	2.5	3.5	5.5	7.5	4.0	1.0	1.0	26

REFERENCES

Frank, N. L., 1974: Atlantic tropical systems of 1974. *Mon. Wea. Rev.*, **103**, 294–300.

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

Lawrence, M. B., 1977: Atlantic hurricane season of 1976. *Mon. Wea. Rev.*, **105**, 497–507.

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

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