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Atlantic Hurricane Season of 1971

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ABSTRACT—A general overview of the 1971 hurricane season in the North Atlantic is presented together with detailed accounts of all named tropical cyclones.

1. GENERAL SUMMARY

The 1971 hurricane season produced a total of 12 named tropical cyclones (fig. 1), only five of which acquired hurricane intensity. Five named cyclones reached the coast of the United States, only two bearing hurricane-force winds at the time. For this reason, property damage and loss of life were relatively low in the United States ($212.58 million in property damage, eight fatalities), the heaviest losses occurring in tropical storm Doria which never reached hurricane intensity but whose heavy rains caused serious flooding in the Middle Atlantic and the New England States. A summary of 1971 hurricane statistics is shown in table 1.

Curiously, seven of the 12 named storms during 1971 formed in the temperate latitudes north of 25°N. Of these, three formed from seedling circulations that had their origins in a persistent zone of convective clouds between latitudes 25° and 30°N. In many respects, this zone resembled the intertropical convergence zone (ITCZ) normally found in this season in the Atlantic near latitude 10°N. This extensive zone of clouds, extending eastward from the Gulf of Mexico to the central Atlantic, which also spawned two depressions, persisted from September 6 to 14. Figure 2 is a satellite photograph of this strange and persistent band of convection. Hurricane seedlings produced in this convective zone were responsible for three of the four named tropical cyclones existing in the Atlantic on September 12.

The establishment of this band of cloudiness was preceded by a very anomalous upper level circulation associated with an anticyclonic eddy centered over equatorial South America. At 200 mb, air streamed from the southeast out of South America across the Caribbean toward the convective zone that established itself north of latitude 25°N. This peculiar circulation was opposite to the mean monthly flow in September. The relationship between this unusual synoptic pattern and the singular lack of cloudiness in the Caribbean and in the ITCZ provides a subject that tropical meteorologists will wish to explore further.

The only hurricanes to acquire notable size and strength during 1971 were Edith and Ginger. Edith, the most severe storm of the season, reached its peak as it approached the coast of Nicaragua on September 9 with a central pressure of 943 mb. However, after passing over the mountains of Honduras and across the Yucatan Peninsula it was able to recover only minimal hurricane-force winds before crossing a sparsely settled area of the Louisiana coast. Hurricane Ginger, whose central pressure fell to 959 mb as it moved eastward between Bermuda and the Azores, will be remembered for a number of other reasons. First, it was the longest lived tropical cyclone of record, existing in various stages of development from September 5 to October 5. Second, Ginger grew to an enormous size as it retraced its path westward toward the United States mainland. Finally, it became the fourth tropical cyclone ever to participate in Project Stormfury modification experiments, seeding operations being conducted on September 26 and 28.

The 1971 hurricane season produced storm systems whose structure and energetics were in sufficient question that they were not classified as tropical cyclones although they acquired unusual intensity before merging into a baroclinic zone in the North Atlantic. The most notable of these was the unnamed storm of July 29–August 7. As this system moved northeastward from a position 600 n.mi. off the New England coast on August 5, an Automatic Picture Transmission (APT) satellite picture (fig. 3) strongly suggested the development of a circular storm of considerable strength. This was verified as the storm passed over a drilling rig located about 200 n.mi. off the southeastern corner of Newfoundland. At the rig, the pressure fell to 974 mb as sustained winds of 78 kt with gusts to 110 kt were recorded from an anemometer 325 ft above the sea surface. The radius of maximum winds was calculated to be on the order of 30 n.mi. Such a wind field would not be inconsistent with the horizontal wind profiles often observed in hurricanes. However, the flux of heat within the system at this time was from the air to the sea with the air temperature 5°C warmer than the sea. During the passage of the storm center, there was no precipitation, no evidence of convective clouds, and dense fog was reported. Thus, the sources of energy in this system were necessarily different from those of a hurricane. The only means by which the observed pressure gradients could have been established is by an atypical lowering of the tropopause over the storm center, bringing stratospheric air down to a relatively low level at the center of the vortex.

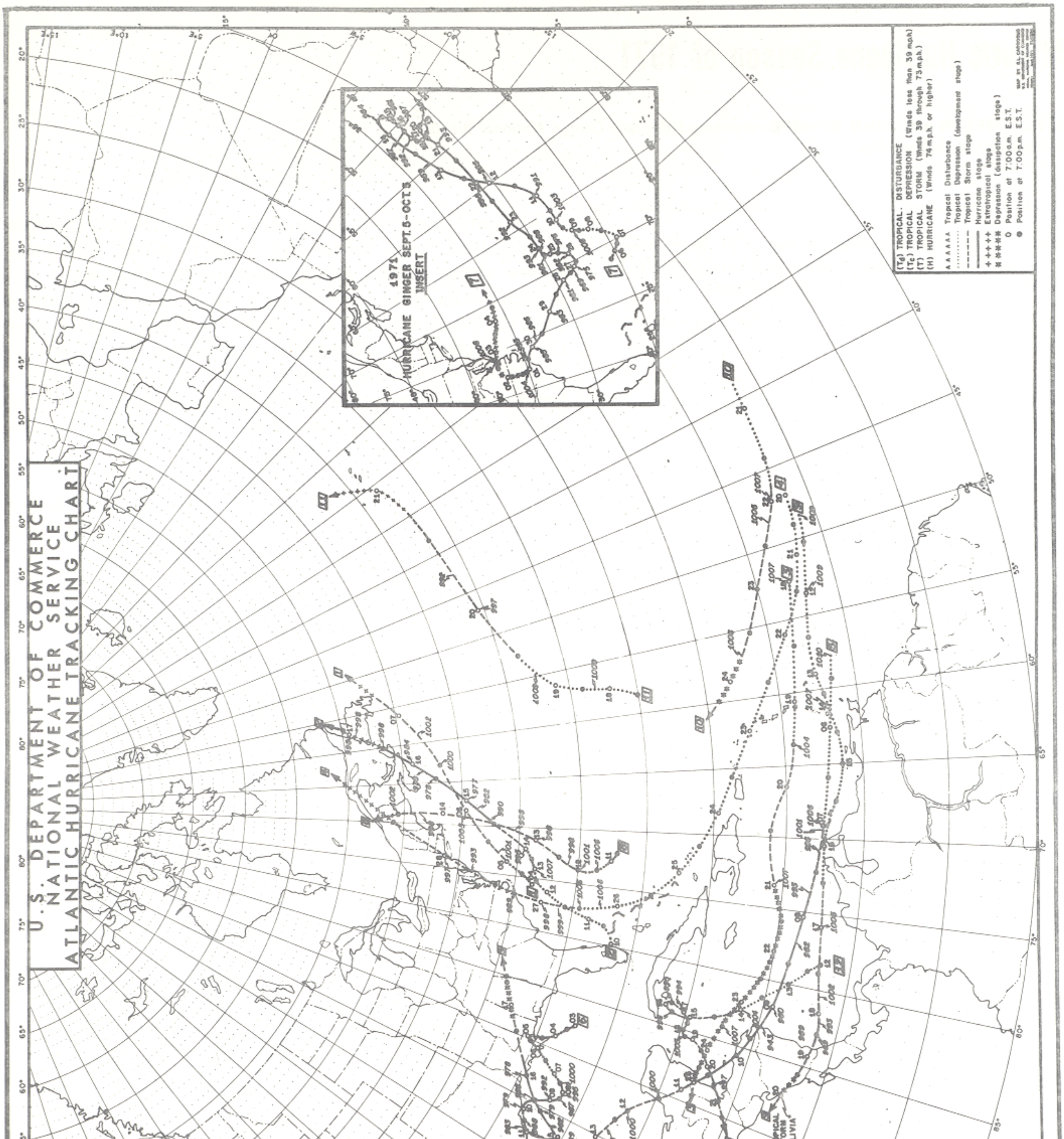

FIGURE 1.—Atlantic hurricanes and tropical storms, 1971.

Table 1.—*Summary of North Atlantic tropical cyclones, 1971*

Storm name	Class*	Date	Coastlines crossed	Max. sust. wind (kt)	Lowest pressure (mb)	U.S. damage (millions $)	Deaths
1. Arlene	TS	July 4–7		52	1000		
2. Beth	H	Aug. 10–17	Nova Scotia, Newfoundland	75	977		
3. Chloe	TS	Aug. 18–25	British Honduras	55	1004		
4. Doria	TS	Aug. 20–29	North Carolina	55	989	147. 35	United States–6 (New Jersey–3, Virginia–1, Massachusetts–1, Pennsylvania–1)
5. Edith	H	Sept. 5–17	Nicaragua, British Honduras, Louisiana	140	943	25. 00	Nicaragua–28 Aruba–2
6. Fern	H	Sept. 3–13	Louisiana, Texas	80	979	30. 23	Texas–2
7. Ginger	H	Sept. 5–Oct. 5	North Carolina	90	959	10. 00	
8. Heidi	TS	Sept. 10–14	Maine	50	996		
9. Irene	H	Sept. 11–20	Nicaragua	67	989		
10. Janice	TS	Sept. 21–24		55	1005		
11. Kristy	TS	Oct. 17–21		55	992		
12. Laura	TS	Nov. 12–21	British Honduras	60	994		Cuba–1

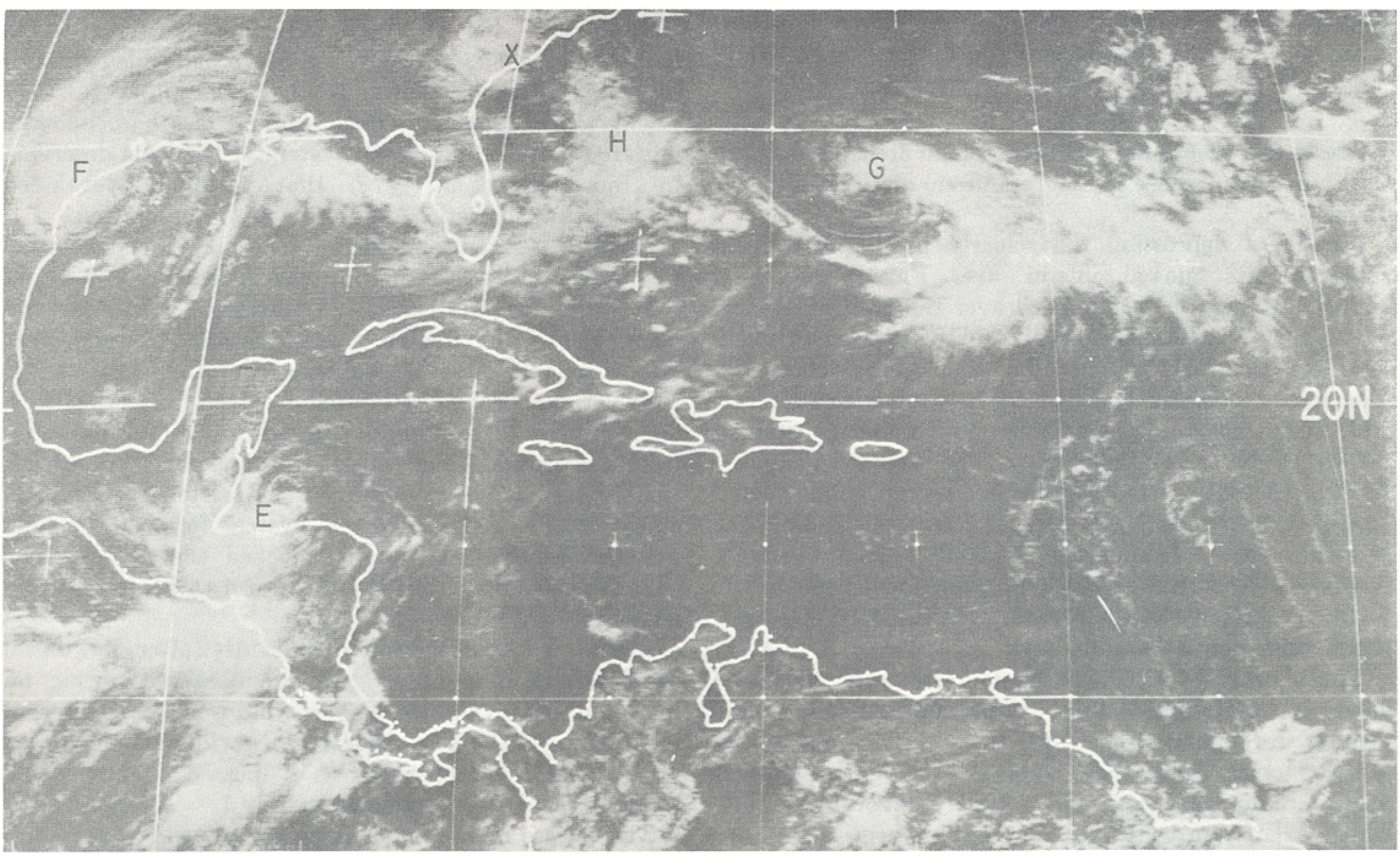

Figure 2.—ATS 3 photograph of persistent zone of cloudiness extending from the Gulf of Mexico eastward into the Atlantic at 1609 GMT on Sept. 10, 1971. Lettered features are: (F), Fern; (G), Ginger; (E), Edith; (H), disturbance from which Heidi developed; and (X), strong tropical depression.

This type of hybrid storm system, referred to as a "neutercane" on previous occasions (Simpson and Pelissier 1971) poses a new challenge to the tropical meteorologist, first in understanding the energetics and structure of such systems and second in identifying and warning of such storms, which surely hold as serious a threat to maritime

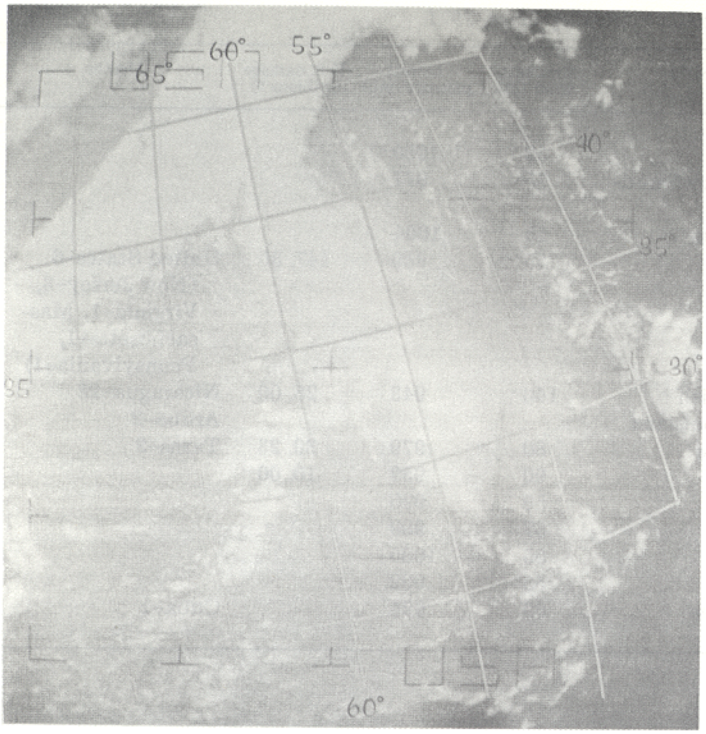

Figure 3.—ESSA 8 satellite photograph of unnamed Atlantic storm at 1412 GMT on Aug. 5, 1971.

interests and occasionally to some island areas as do classical hurricanes whose structure and energetics are better understood.

Finally, a depression that clearly possessed tropical characteristics moved inland over Florida near Ft. Myers on August 13 and back over the Gulf of Mexico on August 15, then deepened rapidly just as it made landfall again early the next day near Steinhatchee, Fla. The lowest pressure reported by reconnaissance aircraft was 1002 mb accompanied by 30- to 40-kt sustained winds. However, at Cedar Key, Fla., somewhat to the right of the path of the depression's center, winds gusted briefly to hurricane force, and local coastal flooding due to rising tides was reported. Rainfall amounts ranging up to 8 in. occurred as the depression moved northeastward through northern Florida, southeastern Georgia, and eastern South Carolina.

The absence of any tropical depressions or storms in June can be attributed to above-normal midtropospheric heights throughout much of the primary generation areas. During July, these anomalous heights persisted in the Bahamas except for a briefly favorable regime when Arlene formed, but the development of a full-latitude trough from the Gulf of Mexico northward resulted in strong shears unfavorable for storm development in that area (Gray 1967). The subtropical ridge shifted northward and strengthened during August, resulting in a positive height anomaly between latitude 40°N and 50°N from the central Atlantic into the northern United States with a negative height anomaly over the eastern United States. This condition has been found favorable for development (Hebert 1969). Three named storms plus the strong depression in the gulf and the unnamed storm all developed just east of this negative anomaly.

A reversal of the large-scale circulation features occurred during the first week of September (Taubensee 1971), the trough over the eastern United States shifting into the Atlantic and a ridge building over the northeastern part of the nation. This resulted in a favorable circulation pattern for development in both the Gulf of Mexico and near longitude 70°W as the trough was progressing eastward (Hebert 1972).

During the 1971 season, there continued to be a general lack of significant hurricane development east of the Lesser Antilles, a factor which has persisted for the past 5 yr. Specific circulation anomalies to explain this overall absence remain elusive, although fairly good relationships can be deduced for individual months.

2. INDIVIDUAL NAMED STORMS

Tropical Storm Arlene, July 4–7

Arlene, the first tropical storm of the 1971 season, was named on July 5 after a reconnaissance crew found that a depression 120 n.mi. off Cape Hatteras, N.C., had strengthened and central pressure had fallen to 1002 mb with sustained winds of 45 kt (at 700 mb).

This storm provided a good example of a baroclinically initiated lower tropospheric system of the type described by Simpson et al. (1970) that gradually developed tropical characteristics due to growth of convection.

On July 4, satellite pictures and coastal reports revealed that a frontal wave formation had become stationary off the North Carolina coast, the movement northeastward being blocked by a high pressure system centered over New England. On the following morning, July 5, the Applications Technology Satellite 3 (ATS 3) revealed a circular mass of cloudiness with spiral banding detached from the frontal cloud mass. Reconnaissance investigation later in the day confirmed the existence of tropical storm Arlene. As the tropical system formed, the high pressure which had initially blocked the new cyclone slipped eastward permitting the storm to begin a steady northeastward movement.

Arlene never deepened significantly after its initial development. The lowest pressure observed during its life was 1000 mb and the highest wind was 52 kt, reported by a ship off the south coast of Newfoundland. Arlene lost tropical characteristics as it passed over the cold waters east of Newfoundland on July 7.

There were no deaths or damages associated with this storm.

Hurricane Beth, August 10–17

The initial evidence of the season's first cyclone to reach hurricane strength was the formation of an upper Low off the east coast of Florida on August 9. On the following day, the circulation reached the surface and formed a tropical depression.

After moving steadily northeastward in a relatively cold environment without further development during the next 2 days, the storm structure gradually changed to a warm core system during August 13 and 14 as the depression passed offshore of Cape Hatteras, N.C. Rapid deepening followed, and Beth was named on August 14 after a reconnaissance plane measured a central pressure of 995 mb. Ten hr later, the surface pressure had fallen to 990 mb, and low-level winds had increased to 68 kt. Beth had become a hurricane.

Beth began moving more rapidly northeastward on August 14 while continuing to gradually intensify. On August 15, the pressure had fallen to 977 mb and surface winds had reached 75 kt as the hurricane passed east of Cape Cod, Mass. Slight weakening occurred thereafter as Beth made for its landfall on the afternoon of August 16 near Copper Lake on the eastern tip of Nova Scotia. Subsequently, the hurricane passed over Cape Breton Island, Nova Scotia, and was swept up by a cold front as it reached southwestern Newfoundland early the next day.

Record rainfall amounts occurred in Nova Scotia. Nearly 10 in. fell in Halifax. Damage to crops, due mainly to flooding, was extensive. Sections of highways and bridges were washed out. Fresh water supplies at Dartmouth remained contaminated for days following the storm because of excessive runoff into the supply lakes.

Total damage in Nova Scotia was estimated at $3.5 million. No fatalities were reported.

Tropical Storm Chloe, August 18–25

The disturbance from which Chloe developed moved off the African coast on August 13. After moving steadily westward for several days, it was identified as a depression on August 18 when satellite pictures indicated increasing circular organization, and a reconnaissance investigative flight found pronounced cyclonic flow around its northern periphery. At that time, the depression was centered about 400 n.mi. east of Barbados. The surface pressure was estimated to be 1007 mb, and surface winds were gusting to 35 kt.

During the depression's traverse of the Windward Islands, sustained winds did not reach gale force although Barbados, Dominica, and Martinique reported gusts to 50 kt, and rainfall amounts of 4–6 in. were reported at Barbados and Martinique. On the 19th, the central pressure had dropped to 1004 mb, but the system continued to be poorly organized. On the 20th, however, sustained winds up to 55 kt were reported northeast of the center by reconnaissance aircraft and surface ships and the cyclone was named. Later in the day, Chloe began to weaken, and by the next morning it was no longer of storm intensity.

Chloe continued across the Caribbean as a depression and for a time conditions favored reintensification. However, a collapse of the ridge to the north reduced low-level inflow. The depression maintained a central pressure of 1007 mb and sustained winds were no more than 30 kt when it passed inland over British Honduras on the morning of August 25. Continuity of movement and satellite pictures suggest that the remnants of Chloe formed the embryo from which hurricane Lily formed in the Pacific on August 30.

Chloe produced no known casualties or significant damage.

Tropical Storm Doria, August 20–29

Even though Doria never attained hurricane status, it was by far the most damaging to the United States of any named storm in 1971. This is because it traversed a heavily populated area of the country, and the heavy rains it carried caused extensive damage to property and crops as rivers and streams overflowed their banks.

The seedling from which Doria grew moved off the African coast in mid-August. On August 20, it had barely reached the depression stage with a central pressure of 1008 mb and maximum sustained winds of 25 kt.

Little change was observed until August 25 when satellite pictures and aircraft reconnaissance indicated better organization. The following day, winds over a considerable area had increased to 35 kt and the tropical cyclone was named as it reached a point 200 n.mi. east of Daytona Beach, Fla., moving on a more northerly track. As the center approached the North Carolina coast, the central pressure fell rapidly, reaching a minimum value of 989 mb as the center moved inland near Morehead City, N.C., on August 27 carrying maximum winds of 60 kt in gusts. As the storm moved northward through the Middle Atlantic States, the center almost straddled the coastline until it moved far inland across New England with gradually weakening circulation.

Much of the rainfall associated with Doria occurred well in advance of the storm, north of a frontal trough that receded northward with the storm. Heavy rains were confined mainly to the area east of the mountains. In New England, however, heaviest amounts were west of the storm track. Rainfall, wind, pressure, and tidal extremes for selected stations are shown in table 2. Eight to 10 in. of rain were reported at a number of locations in eastern Maryland, Delaware, New Jersey, and southeastern New York. More than 6 in. was reported in southeastern Pennsylvania, western Massachusetts, and Vermont. From Maine northward, lesser amounts were recorded as the storm accelerated north-northeastward and acquired extratropical characteristics.

Wind gusts of 60 kt were measured at Atlantic Beach, N.C., near the point of landfall, and gusts to 50 kt were reported along the Outer Banks and the shores of Pamlico and Albermarle Sounds.

Streets and highways in many areas were blocked by flood waters and some by mudslides. Considerable damage was done to water and sewer systems. Many power systems were interrupted temporarily, and in some areas flooding severely damaged residential and industrial properties. In most areas wind damage was minimal, affecting mainly shrubbery, trees, and power lines. How-

TABLE 2.—*Tropical cyclone data for tropical storm Doria, Aug. 20–29, 1971* [*from Environmental Data Service* (*EDS*), *NOAA*]

Station	Date	Pressure		Wind				Highest tide*	Time	Storm rainfall	Remarks
		Low	Time	Fastest mile	Time	Gusts	Time				
	Aug.	(in.)	(EST)	(mi/hr)	(EST)	(mi/hr)	(EST)	(ft)	(EST)	(in.)	
SOUTH CAROLINA											
Charleston	27	29. 77	0500	NW 22	1057			5.7 MLW	1148	T	1.75 in. at Ocean Drive Beach
NORTH CAROLINA											
Wilmington	27	29. 68	1201	N 21	1159	N 30	1222	2 AN		2. 19	Tide at Cape Fear
Hatteras	27	29. 61	1557	SSE 41†	1557	S 54	1600			4. 17	
Elizabeth City	27	29. 33	1800			60					
VIRGINIA											
Norfolk	27	29. 37	1951	NE 52	1837	NNE 71‡	1909	3.6 AN		3. 09	Tornado confirmed 10 mi west-southwest of Norfolk Regional Airport
Richmond	27	29. 79	2158	SE 17	1347					1. 40	
DISTRICT OF COLUMBIA											
Washington National Airport	28	29. 77	0100	NW 19	0014	W 26	0844			3. 85	
MARYLAND											
Salisbury (FAA)	27	29. 39	2330	ENE 36	2210	ENE 50	2210			3. 34	
Assateague Island	27			SE 30	2215	50	2215	2 AN		3. 58	
Baltimore (WSO)	27	29. 75	28/0032	N 18	2347			2.7		4. 39	Tide at Ft. Henry
Ocean City (C. G. Station)	27	29. 33	28/0000 28/0100	E 23	2200	E 63	2330				
DELAWARE											
Wilmington	28	29. 56	0156					3.2 AN	0000	5. 09	Tide at Lewes
PENNSYLVANIA											
Philadelphia	28	29. 44	0250	NW 51	0355	NW 73	0430			6. 57	
NEW JERSEY											
Atlantic City	28	29. 37	0230	SE 35	0055	SE 54	0048	5.3	0050	1. 88	
Trenton	28	29. 43	0145	NE 43	0159					8. 09	7.55 in. rain in 24 hr set record for station
Newark	28	29. 46	0455	NW 23	0554					8. 01	
NEW YORK											
New York City (WSO)						NE 48	0335				
	28	29. 43	0515	SE 32†	0424	SE 48	0424	3.8	0548	5. 96	Tide at the Battery
New York City (J. F. K.)	28	29. 44	0530	NW 32	0711	ESE 44	0308			3. 69	
New York City (LGA)	28	29. 43		S 40	0415	E 40	0252			5. 49	2.29 in. of rain, 1340–1440 on the 27th
CONNECTICUT											
Hartford	28	29. 51	0745	SE 37	0645	SSE 48	0726			3. 12	
RHODE ISLAND											
Providence	28	29. 66	1018	SSE 44†	0738	SSE 61	0737	5.9 MLW		0. 97	
MASSACHUSETTS											
Boston	28	29. 62	1056	SSW 45	1018	SE 56	0857			0. 83	
MAINE											
Portland	28	29. 63				45					

* Tide above mean sea level (MSL) unless noted; AN–above normal, MLW–above mean low water
† One-minute wind speed
‡ Anemometer at 60 ft

ever, a tornado which touched down near the airport at Norfolk, Va., caused property damage estimated at $250,000.

Table 1 shows that total damage from Doria is estimated to be $147.35 million. Six persons lost their lives in the storm.

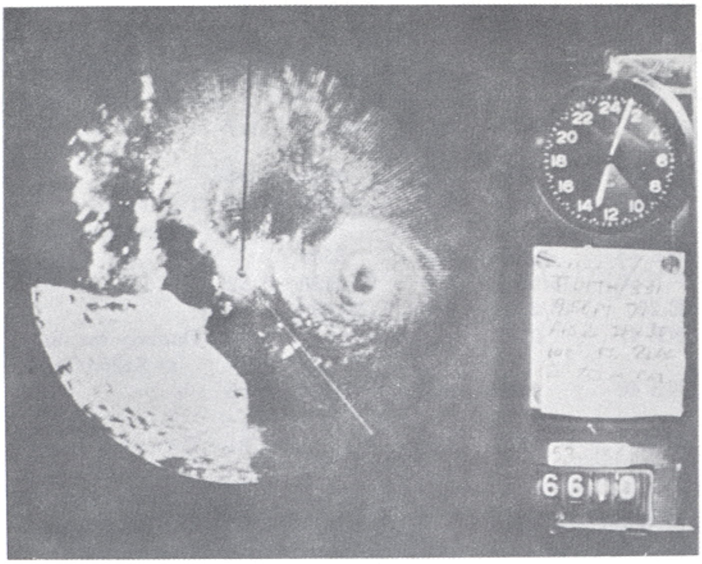

FIGURE 4.—Airborne radar photograph of hurricane Edith as it approached Cape Gracias, Nicaragua, at 1303 GMT on Sept. 9, 1971 (Courtesy U.S. Navy).

Hurricane Edith, September 5–17

Hurricane Edith was the only hurricane of the 1971 season to qualify as a major hurricane. Its central pressure fell to 943 mb and sustained winds reached 140 kt just as it slammed ashore at Cape Gracias, Nicaragua.

The seedling disturbance which later became Edith was first noted on September 2 when it appeared as a small circular cloud mass within the ITCZ near 12°N, 35°W. As the seedling moved steadily westward for 3 days, it became detached from the ITCZ and on September 5 a reconnaissance plane reported that a depression centered near 11.5°N, 57.0°W had formed. That night, the depression passed through the southern Windward Islands producing heavy rains and sustained winds of 30 kt.

Edith was named on September 7 after a reconnaissance plane found a central pressure of 1006 mb at 1230 GMT. Ninety min later it had fallen to 1001 mb. Early the following day, Edith reached hurricane strength with sustained winds of 65 kt and a central pressure of 993 mb. For 36 hr, pressures fell steadily to a low of 960 mb. Then during the next 6-hr period as the center approached Cape Gracias on September 9, the pressure fell rapidly to 943 mb. A reconnaissance plane at 5,000-ft elevation measured sustained winds of 140 kt just before the center reached the coast at midday. The reconnaissance crew reported extreme turbulence, jeopardizing the integrity of the aircraft and safety of the crew. Edith's perfectly formed eye shrank at times to 5 mi. in diameter. Figure 4 is a radar photograph taken by a reconnaissance flight at 1303 GMT on September 9 as the hurricane approached Cape Gracias.

Edith quickly lost strength as it crossed northern Honduras. However, southwest winds up to 50 kt were reported at some small keys off the coast of British Honduras. Further loss of intensity occurred as the center again moved inland over British Honduras. It had difficulty in maintaining its identity as it crossed the Yucatan Peninsula before emerging into the Gulf of Mexico near Campeche, Mèxico.

Little reintensification occurred as Edith moved west-northwestward across the southwestern Gulf of Mexico. It stalled off Soto la Marina, Mexico, on the evening of September 13, then drifted slowly northward. On the morning of September 15, Edith began accelerating northeastward while regaining strength. By noon on the 15th, it had regained hurricane status with a central pressure of 982 mb and sustained surface winds of 65 kt.

This storm's third and final landfall occurred in a sparsely settled area of the Louisiana coast about 25 n.mi. east of Cameron early September 16. Inland it weakened rapidly, losing its identity entirely in northern Georgia September 18.

Edith was anomalous in several ways. In addition to its small size and great fury, it developed farther south and east than most September storms in the Caribbean. During its odyssey, it made landfall three times.

In the Caribbean, the course of Edith was controlled by a narrow persistent ridge of high pressure extending from the southwestern Atlantic to the southern Gulf of Mexico, which protected the hurricane from meridional currents that would have turned it northward. However, as it approached the Mexican coast, it came under the influence of a midlatitude trough which deepened and extended its circulation into south Texas, causing the storm to move to the northeast.

The meteorological factors supporting the explosive deepening of Edith in the Caribbean are of special interest. The 200-mb charts on September 7, the day Edith was named, show a well-defined cold cyclone centered about 650 n.mi. northwest of the vortex. As the storm traveled westward, the upper level cyclone weakened and was replaced by an anticyclone. Similar sequences notable during the explosive deepening of Camille in 1969 and Celia in 1970 prompted Riehl[1] to suggest that the transformation in the upper troposphere may be the source of baroclinic releases of energy which cause explosive deepening in some hurricanes. However, while Edith was still a depression on September 6, it was moving into an area of light vertical shear and high thickness values as depicted on the National Hurricane Center (NHC) tropospheric shear charts. This has been found to be a required combination if an incipient disturbance is to develop (Gray 1969). Lack of upper air data over the extreme southern Caribbean and the impossibility of reconnoitering the hurricane over land to the south of its center in early stages made it difficult to assess the character of the low-level inflow or the upper level outflow.

Edith weakened over Yucatan and failed to regain intensity in the southwestern Gulf of Mexico, but a more favorable environment for strengthening was encountered after the remnants of hurricane Fern moved westward

[1] Herbert Riehl discussed this concept in a lecture to the Greater Miami Chapter of the American Meteorological Society, Sept. 22, 1971.

TABLE 3.—*Tropical cyclone data for hurricane Edith on Sept. 5–17, 1971 (from EDS, NOAA)*

Station	Date	Pressure Low	Pressure Time	Wind Fastest mile	Wind Time	Gusts	Time	Tide* Highest	Tide* Time	Storm rainfall	Remarks
		(in.)	(CST)	(mi/hr)	(CST)	(mi/hr)	(CST)	(ft)	(CST)	(in.)	
TEXAS											
Brownsville (WSO)	15	29. 53	0600	NW 27	0958	W 32	1604	1. 8	0515	2. 34	
Corpus Christi	15	29. 60	1620	NE 21	1213	NE 28	1318	2. 2	0900	0. 57	Tide at Port Aransas
Freeport	16	29. 54	0600	NNE 40	0500	NE 45	0500	3. 0	0500		
Galveston (WSO)	16	29. 54	0300	NE 35	15/2314	NE 53	15/2317	4. 0	0150	0. 82	
Houston (WSO) IAH	16	29. 69	0155	ENE 18	15/2329	E 25	15/2209	3. 3	15/1500	T	
Port Arthur (WSO)	16	29. 54	0507	E 40	0443	NE 47	0443			3. 02	Damage estimated at $125,000
Sabine Pass	16	29. 58	0300	NE 35	0300	NE 40	0200	4. 0	0200	3. 50	
LOUISIANA											
Baton Rouge (WSO)	16	29. 25	1207	SE 46	1106	S 64	1122			4. 31	Tornado reported in eastern residential suburbs
Boothville	16	29. 79	1500	SW 28	1234	SSW 58	1215			2. 03	Tornado reported at Venice
Cameron	16	29. 39	0600	NNE 69	0700	NNE 96	0700	4. 7	0400		
Lafayette	16	29. 11	1014	ESE 46	0939	ESE 69	0939			5. 15	
Lake Charles	16	29. 49	0702	NNE 47	0803	NNE 58	0737			2. 99	
Morgan City	16	29. 60	1035	WSW 30	1115	SSE 72	1030	5. 8	1215		Tide at Cypremort Point was 9.7 ft
New Orleans (WSO)	16	29. 71	1250	SSE 32	1105	SE 51	0921			4. 64	
St. Francisville	16	29. 51	1240	WNW 50	1135	WNW 61	1144			4. 10	
MISSISSIPPI											
Bay St. Louis	16			SW 45	1230	SW 65	1230			2. 85	
Columbia	16	29. 61	1530	SE 42	1500	SE 55	1500			1. 18	
Hattiesburg	16	29. 74	1455	NW 45	1455	NW 70	1455				
Jackson (WSO)	16	29. 71	1822	NE 33	1934	NE 49	1702 1806			4. 77	
Liberty	16									6. 15	
McComb	16	29. 00	1400	WNW 21	1600	SSE 40	1300			2. 85	
Tylertown	16	29. 34	1500	SE 35	1500	SE 48	1500			3. 45	
ALABAMA											
Mobile (WSO)	16	29. 83	1645	SSE 29	1405	S 43	1403	2. 7	1900	2. 33	
Birmingham (WSO)	17	29. 90	0300	NE 18	16/2319	E 31	16/2301			1. 94	
FLORIDA											
Pensacola (WSO)	16	29. 88	1658	S 21	1759	S 30	1759	0. 8		0. 53	Tornado reported near Pensacola

*Tide above MSL

across Mexico. This allowed the flow in the western Gulf of Mexico, which had previously fed into the vortex of Fern, to enhance the boundary layer transport of mass into Edith.

Two fishermen were reported lost at sea as Edith passed over Aruba on September 7. Sustained winds of 35 kt were reported at Aruba and gusts reached 50 kt. There were 28 confirmed fatalities and 1,876 people left homeless when Edith struck the Cape Gracias area of Nicaragua. Unofficial reports have placed the toll much higher, but no confirmation of the higher estimates has been obtained.

A meteorological summary for selected U.S. stations is shown in table 3. As Edith passed off the Texas coast, Galveston recorded gusts to 45 kt (53 mi/hr). Tides of 6 ft above normal occurred at Sabine Pass, Tex. Damage to crops and property in Texas was estimated to be less than $200,000.

In Louisiana, highest sustained winds were 60 kt (69 mi/hr) measured at Cameron where gusts reached 83 kt (96 mi/hr). A strong rain band well in advance of the hurricane center spawned several tornadoes in southern Mississippi and Louisiana on September 16, one of which caused considerable property damage along an intermittent 7-mi path through Baton Rouge, La.

Rainfall amounts up to 8 in. were reported in southwestern Louisiana, with not more than 2–3 in. elsewhere in the southeastern states.

Total United States damage caused by Edith is estimated at $25 million, most of which was crop losses in Louisiana. Storm tides in Louisiana near the point of landfall reached 8 ft above normal, the highest being reported at Vermilion and Cote Blanche Bays. No United States fatalities have been attributed to Edith.

Hurricane Fern, September 3–13

The track of Fern, including its depression stage, was most unusual. It is also rare for a depression to move inland over the continental United States (except over peninsular

TABLE 4.—*Tropical cyclone data for hurricane Fern on Sept. 3–13, 1971*

Station	Date	Pressure		Wind				Tide*		Storm rainfall	Remarks
		Low	Time	Fastest mile	Time	Gusts	Time	Highest	Time		
		(in.)	(CST)	(mi/hr)	(CST)	(mi/hr)	(CST)	(ft)	(CST)	(in.)	
TEXAS											
Beaumont/Port Arthur	10	29.60	0344	E 28	0001	NE 36	9/2341	3.0	0300	1.07	Funnel cloud sighted 20 mi west of Jefferson County Airport at 1012 on the 10th
Houston (International Airport)	10	29.56	0310	ENE 27	1255	E 32	1255		0800	2.62	Total rainfall downtown was 4.79 in. Tide at Baytown, 5.3 MSL at 0900 on the 10th
Sabine Pass (USCG)	10	29.60	0600	E 28	0400			4.0	0540	3.50	Tide between Sabine Pass and High Island was 4.8 ft MSL
Galveston	10	29.44	0215	E 43	9/2241	E 60	9/2238	5.5	0100	5.26	Galveston Coast Guard Station reported a peak gust of 70 mi/hr; 5.3-ft tide at Baytown
Freeport	10	29.35	0700	NNE 39	9/2300	NNE 58	0130	6.0			
Palacios (FSS)	10	29.33	0556			NW 63	0430			10.38	
Victoria	10	29.44	1700	N 49	0949					6.20	
Point Comfort	10	29.36	0800	N 52	0812	N 62	0720				
Seadrift	10	29.37	1300	NNE 55	1300	NNE 65				9.48	Reports from Matagorda Island indicate winds of 60–70 mi/hr with gusts to 90 mi/hr
Bayside	10	29.20	1400	50		NW 65	1400			16.00	
Rockport	10	29.12	1915	NNE 35		NNW 56	1438			7.61	
Aransas Pass	10	29.04	2030	E 55	2355	E 78	2355	5 AN		11.50	Gusts on St. Joseph Island reported at 85 mi/hr. Thousands of swallows seen in eye of Fern
Corpus Christi	11	28.98	0154	NW 66	10/2118	NW 70	10/2128	3.0	2330		Tide at Port Aransas Tide at Rockport was 3.9 ft MSL at 0500 on the 12th. One swimmer drowned at Corpus Christi City Marina on the 11th. Another death was reported near Refugio on the 12th
Brownsville (WSO)	11	29.58	1555	W 32	1434	NW 41	10/1726	2.1		0.02	

*Unless indicated, tides are above MSL; AN above normal

Florida), then move back over the water and acquire storm or hurricane intensity. During its life, Fern abruptly changed heading by 90° or more three times.

Fern originated from a tropical wave which moved northwestward out of the Caribbean Sea on September 1. A closed circulation in the middle troposphere moved over south Florida on September 2. The next day, it became a depression as the circulation extended throughout the troposphere. Continuing northwestward, it moved inland over southern Louisiana on September 4, bringing up to 7 in. of rain in the New Orleans area. On September 6 and 7, responding to increased circulation in a ridge over the central United States, the depression moved southwestward gaining strength slowly over the warm waters of the western Gulf of Mexico. It reached storm intensity late on September 7 and became a hurricane on the following day with sustained winds near 80 kt. About 180 n.mi. southeast of Galveston, Tex., with the approach of a midlatitude trough, Fern became almost stationary for nearly 12 hr. Then, responding to the trough, Fern turned northwestward toward Galveston. However, as the trough proceeded eastward at higher latitudes, pressures began to rise over Texas and Fern, after remaining stationary off Galveston for several hours, turned slowly southwestward, paralleling the Texas coast.

The storm center, which had become elongated, edged inland on the morning of September 10 between Freeport and Matagorda, Tex.; by midmorning Fern was no longer of hurricane strength. However, because a portion of its elongated center remained over the Gulf waters, weakening was very slow. During the night of September 10–11, Fern passed over Corpus Christi, Tex., after which it turned toward the west-southwest and finally was reduced to depression strength as it crossed the Rio Grande River into Mexico. A summary of meteorological data associated with Fern in Texas is shown in table 4.

Most of the damage in Texas resulted from destructive floods caused by heavy rains. Accumulations ranging from 15 to 26 in. were reported in Bee, Refugio, and San Patricio Counties, while totals of 10–15 in. fell over Calhoun, Aransas, Matagorda, Goliad, and Duval Counties. From Galveston to Rockport, Tex., amounts ranged from 5 to 12 in. More than 8 in. was measured as far inland as Laredo.

Numerous towns in Texas were isolated or seriously flooded. Major flooding occurred along the lower Nueces River and along portions of the Frio, Lavaca, Navidad, San Antonio, Guadalupe, Mission, and Aransas Rivers.

Highest sustained winds at Corpus Christi, Tex., were 57 kt (66 mi/hr), and at Port O'Connor 75, kt (86 mi/hr). Gusts of 50 kt (58 mi/hr) or higher were reported from Galveston to south of Corpus Christi. Five tornadoes observed in Texas were associated with Fern. Storm tides of 5–6 ft above normal occurred in the Galveston-Freeport area.

Total damage caused by Fern is estimated at $30.23 million, mostly to property in Texas. Two persons were drowned.

Hurricane Ginger, September 5–October 5

Ginger will be noted chiefly for its longevity, circuitous track, and as the lone hurricane to provide Project Stormfury with a seeding target during the 1971 season.

This storm was tracked for 31 days, during 20 of which it was a hurricane. The 31-day total life exceeds that of Faith of 1966 (26 days) and Carrie of 1957, which was a hurricane for 18 days. Inga of 1969 persisted as a named system for 25 days.

The depression formed on September 5 when an upper level low warmed and extended downward to the surface. It drifted for 4 days, slowly becoming better organized before reaching storm intensity on September 10. Ginger initially moved eastward but, after acquiring hurricane intensity on September 11, accelerated northeastward.

After maintaining a northeastward track until September 13, Ginger turned eastward as it deepened to 959 mb and acquired estimated sustained winds of 90 kt. At this juncture, further eastward movement was blocked by a building ridge of high pressure to the north and east. There followed a slow looping drift westward while the lowest pressure in the hurricane rose to 993 mb. On September 21, Ginger began a determined movement toward the west at 10 kt, briefly threatening Bermuda, but finally passing about 100 n.mi. south of that island on September 23. On September 24, it again hesitated and began a slow drift toward the southwest that continued for 3 days during which time the central pressure again fell to a low of 975 mb. On September 27, Ginger turned toward the northwest and gradually set a steady course toward the North Carolina coast, moving inland near Morehead City on the evening of September 30. Maximum sustained winds were 65 kt and minimum pressure was 993 mb as it reached the coast. After meandering inland to the north and east, it emerged back over the Atlantic as a depression on the morning of October 3, and was finally absorbed by a cold front.

Ginger, for reasons not entirely understood, remained in a remarkably steady state near the threshold of hurricane strength during most of its life span over the subtropics, and reconnaissance crews noted a singular lack of penetrative convection most of the time. The hurricane maintained an unusually large atypical eye formation, sometimes 80 mi in diameter. Table 5 is a summary of meteorological data associated with Ginger in the United States.

As the hurricane passed 100 n.mi. south of Bermuda, gale-force winds raked the island for 17 hr. At the Kindley Naval Air Station, maximum sustained winds were 30 kt with gusts to 65 kt. Tides on Pamlico Sound were 4–7 ft above normal. At Washington, Aurora, New Bern, and Cherry Point, N.C., tides were 6 ft above normal.

Rains of 10–13 in. were reported in several east-central North Carolina counties, where there was severe damage to crops.

Total damage in North Carolina is estimated at $10 million. There was no appreciable damage in Virginia. No fatalities were ascribed to hurricane Ginger.

Tropical Storm Heidi, September 10–14

The disturbance from which Heidi developed was one of five systems noted earlier that developed in a trough of low pressure that persisted for more than a week, extending from the northern Gulf of Mexico eastward across Florida and the Bahamas into the southwestern Atlantic. At times, the wind shift in the low levels associated with the trough was concentrated into a sharp shear line. The ATS 3 picture taken September 10 (fig. 2) shows this convective area, which includes Fern, Ginger, and the disturbance from which Heidi originated.

Heidi never became a well-developed tropical system, but reconnaissance reports showed that it did have a warm central core. The lowest pressure was 996 mb and maximum sustained winds were 50 kt. The cloud pattern as seen on satellite pictures showed that the main overcast region covered the western sector, and there was never good evidence of outflow at the cirrus level.

Heidi reached tropical storm strength when located about 400 n.mi. east of Jacksonville, Fla. As it approached New England, a large low-pressure system developed over the northern Appalachian Mountains, the circulation of which completely engulfed Heidi a few hours before the storm moved inland over Maine. Maximum sustained winds had decreased to less than gale force when it crossed the Maine coast on the afternoon of September 14.

No casualties or damages due to Heidi were reported.

TABLE 5.—*Tropical cyclone data for hurricane Ginger from Sept. 5 to Oct. 5, 1971 (from EDS, NOAA)*

Station	Date	Pressure		Wind				Tide*		Storm rainfall	Remarks
		Low	Time	Fastest mile	Time	Gusts	Time	Highest	Time		
		(in.)	(EST)	(mi/hr)	(EST)	(mi/hr)	(EST)	(ft)	(EST)	(in.)	
NORTH CAROLINA											
Atlantic Beach	30	29. 56	0130			NW 92	0305	4.0 AN			
Hatteras	30	29. 43	1157	SE 44	0857	SE 70	0912			9. 68	Ocean tides 2–3 ft above normal
Topsail	30	29. 35	1600			WNW 58	1600				
Holden Beach	30	29. 52	1700			WNW 35	1700				
Wilmington	30	29. 46	1901	NW 32	1200	WNW 44	1122			1. 19	
Raleigh	01	29. 67	0500	NNW 32	30/1709	N 46	30/1444			3. 50	
Charlotte	01	29. 82	1359	N 22	30/1150	NNE 30	30/1256			2. 21	
VIRGINIA											
Norfolk	30	29. 77	1430	NE 49	0935	NNE 50	0920	2.5 AN	1830	7. 61	Near North Carolina border tides 3–4 ft above normal
Richmond	02	29. 76	1355	NE 21	30/1500	N 25	30/1320			1. 83	
MARYLAND											
Salisbury (FAA)	02	29. 82	0000	SSE 13	1430	SSE 26	1200			0. 82	
Indian River Inlet	03	29. 91	0200	NE 28	0200			2.3	1934		
Ocean City	03	29. 71	0300	E 26	0700					0. 33	
DELAWARE											
Dover AFB	02	29. 83	1555	ENE 23	01/1406	ENE 29	01/1420			0. 18	

*Tide MSL

Hurricane Irene, September 11–20

The disturbance that grew into hurricane Irene moved off the African coast on September 7 and traveled quite rapidly westward, becoming a depression about 700 n.mi. east of the Windward Islands on September 11. Further immediate strenghtening was inhibited by the presence of the mid-Atlantic trough and the unfavorable influence of Ginger to the northwest.

The depression entered the Caribbean at low latitudes and moved westward along the South American coast. Its broad, ill-defined center crossed Curacao on September 16, maintaining a central pressure of 1008 mb and maximum sustained winds of 35 kt. As the depression moved into the western Caribbean on September 17 leaving the inhibiting influence of the upper trough and the South American land mass, it began to deepen slowly, becoming a named storm about 300 n.mi. east of San Andrés. Irene was upgraded to a hurricane on September 18 when sustained winds reached 67 kt. The ATS 3 movie loop at this time showed the development of an eye and spiral banding extending from the Pacific Ocean across Panama into the cyclone.

Wind gusts reached 37 kt at Barbados and gale-force winds were reported at San Andrés on September 18. Bluefields, Nicaragua, reported sustained winds of 40 kt on September 19. There were no reports near the point of landfall in Nicaragua, where it is likely that hurricane-force winds occurred. Irene was the first hurricane to enter Nicaragua south of Bluefields since 1911.

A 24-hr rainfall of 3.35 in. was reported at Trinidad as the storm passed to the north. Satellite pictures suggested that heavy rains occurred from Honduras to Panama.

On September 20, the remnants of Irene moved into the Pacific, regenerated, and became tropical storm Olivia, which eventually became a 100-kt hurricane.

Although there have been no confirmed reports of deaths or estimates of damage near the point of landfall, a reconnaissance flight noted visible damage along the sparsely settled coastline.

Tropical Storm Janice, September 21–24

A disturbance that moved off the African coast on September 18 became a depression on September 21 and reached storm strength the following day. Maximum sustained winds of 55 kt were confined to the north and east of a broad, poorly organized system. The lowest pressure was 1005 mb.

Janice was already weakening on September 23 and was reduced to a depression the next day. Thereafter, the circulation disappeared rapidly, and the remaining elongated cloud mass became absorbed in the circulation around hurricane Ginger.

It is believed that Janice, even while in an area climatologically favorable for intensification, weakened when it moved into an area of strong vertical wind shear that separated the lower level wind circulation from the convective cloud mass of the storm. This shear field appeared to be related to the anomalous high-level wind field associated with hurricane Ginger.

Some heavy rains fell in the Leeward Islands as the storm passed to the north. St. Kitts reported 4.10 in., most of which occurred during a late evening thunderstorm.

There were no reports of casualties or damages attributed to Janice.

Tropical Storm Kristy, October 17–21

Kristy's initiating disturbance was enhanced as a tropical wave that had been followed across the Atlantic on satellite pictures interacted with a concentrated pattern of convective cloudiness that extended from near Curacao northeastward over Puerto Rico on October 11. At the outset, the cloud mass was closely associated with an upper trough, but the low-level flow was disturbed only slightly. Warming and development ensued gradually, and a tropical depression developed on October 18 about 500 n.mi. northeast of Puerto Rico.

Maximum winds reached 30 kt on October 19. However, satellite pictures and peripheral ship reports indicated that the depression was intensifying. Confirmation of intensity was obtained early on October 20 when Kristy passed close to ship 4YE, where the pressure dropped to 997 mb and maximum sustained surface winds reached 40 kt.

During the afternoon of October 20, the United Kingdom ship *Potosi* (GQPL) located about 600 n.mi. west-southwest of the Azores, reported a Beaufort force 9–10 wind shifting cyclonically to the north. Sea-level pressure was 992 mb.

Even as Kristy was named, a rapidly moving cold front sweeping southeastward over the north Atlantic began to bring colder, dryer air into its circulation, and by nightfall on October 20, Kristy no longer appeared as an entity separate from the cloudiness associated with the cold front. The remnants of Kristy passed through the northwestern Azores as a frontal wave on the morning of October 21. The maximum sustained wind reported in the Azores was 35 kt.

There were no reports of damage or casualties associated with tropical storm Kristy.

Tropical Storm Laura, November 12–21

The tropical depression from which Laura formed developed in the southwest Caribbean about 150 n.mi. north of Panama along the southern edge of a large cloud mass that had grown for several days as it spread northward from Panama.

After its formation, the depression moved northwestward strengthening slowly and became a tropical storm on November 14. It continued a steady northwestward movement at 10 kt for another day, after which it slowed and looped anticyclonically as it approached western Cuba and the Isle of Pines. Upon completion of the loop on November 17, the storm drifted westward for a day and a half, then began moving southwestward; it went inland near Punta Gorda, British Honduras on November 21.

Laura reached its maximum intensity as it completed its loop, when the pressure dropped to 994 mb accompanied by maximum sustained winds of about 60 kt. Laura weakened while drifting westward, but regained most of its former strength just before landfall.

As Laura moved northwestward after reaching storm intensity, a large high-pressure system dominated the eastern part of the United States. However, falling pressure ahead of an approaching cold front in the central United States made it appear for a time that the High would give way enough for a northerly component of motion to continue. But, as the upper level trough associated with the cold front moved northeastward, the high pressure held over the Southeastern States, blocking northward progress of the storm. Steering forces remained delicately balanced for the next 2 days, during which time the storm's path formed a small loop. Then, rising heights and pressures over the western Gulf of Mexico resulted in a southwesterly steering current that carried Laura into British Honduras.

Heavy rains fell north and east of Laura as it neared Cuba. Nearly 20 in. of rain fell over the Isle of Pines. The highest wind reported over land was 60 kt with gusts to 70 kt on the Isle of Pines at 1800 GMT on November 16.

One death was reported in the Pinar del Rio province of Cuba, where 20 homes and some tobacco sheds were destroyed. There were no reports of casualties or damange from British Honduras or Guatemala.

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Atlantic Tropical Systems of 1971

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ABSTRACT—The 1971 hurricane season featured 103 seedlings, 23 depressions, and 12 named storms. An anomalous circulation pattern developed over the Gulf of Mexico and the southwestern Atlantic Ocean in September and spawned a large number of depressions and storms within the subtropical belt near or north of latitude 25°N.

1. INTRODUCTION

This is the fifth in a continuing series of annual articles whose purpose is to highlight salient features of the previous hurricane season with special emphasis on the weaker synoptic scale systems. Details on the named storms that occurred in 1971 are contained in a companion article by Simpson and Hope (1972).

Terms were defined in two previous papers by Simpson et al. (1968, 1969). The basic purpose of this effort is to identify and document the history of all synoptic scale tropical perturbations that developed during the hurricane season (June 1–November 30). Prior to the satellite era, it was impossible to maintain continuity on tropical systems traversing the Atlantic Ocean, because of data considerations. The satellite has given us the tool to bridge this gap.

The Atlantic disturbances have been divided into two categories based on their cloud distribution. If the stratocumulus field that normally exists over the eastern tropical Atlantic Ocean north of the intertropical convergence zone (ITCZ) is organized into an "inverted V" pattern, the system has been labeled a "tropical wave," suggesting that the region of cyclonic vorticity is within the trade winds belt. A second type of disturbance, which has been labeled "ITCZ disturbance," appears to be directly related to the equatorial trough and is revealed by a concentrated area of convection on the ITCZ. The influence of these ITCZ disturbances generally does not affect the stratocumulus; however, in late August and early September when the ITCZ reaches its northern-most position this is not always true, and it is more difficult to assign a disturbance to one of these two categories. We realize that this arbitrary division is tenuous and may have to be refined when data collected in the Global Atmospheric Research Program (GARP) Atlantic Tropical Experiment (GATE) becomes available. We may find that a greater

TABLE 1.—*Summary of the history of tropical waves and disturbances in 1971*

Dakar passage	Nature	Formed in Atlantic	Weakened in Atlantic	Barbados passage	Nature	Weakened in Caribbean	Formed in Caribbean	San Andrés passage	Nature	Atlantic storm	Pacific storm
							X	June 2	ITCZ		
		X ITCZ	X								
June 3	Wave			June 7	Wave			June 12	Wave		Bridget
								June 7	ITCZ		
June 7	Wave			June 12	Wave			June 15	Wave		
June 11	ITCZ			June 16	ITCZ			June 19	ITCZ		
June 12	Wave			June 17	Wave	X					
June 13	Wave		X								
June 17	Wave			June 23	Wave			June 27	Wave		
		X		June 20	Wave			June 22	Wave		
June 20	Wave			June 27	Wave			July 1	Wave		Eleanor
		X ITCZ	X								
June 22	Wave		X								
June 23	Wave			June 29	Wave			July 3	Wave		
								June 25	Wave		Carlotta
		X ITCZ	X								
June 27	Wave			July 3	Wave			July 7	Wave		
							X	June 28	ITCZ		Denise
							X	June 30	ITCZ		
June 29	Wave			July 5	Wave			July 8	Wave	Dep.	
July 1	Wave			July 8	Wave			July 11	Wave		
							X	July 14	ITCZ	Dep.	
July 4	ITCZ		X								
		X ITCZ	X								
July 6	Wave			July 12	Wave			July 15	Wave		
July 9	ITCZ		X								

TABLE 1.—*Concluded*

Dakar passage	Nature	Formed in Atlantic	Weakened in Atlantic	Barbados passage	Nature	Weakened in Caribbean	Formed in Caribbean	San Andrés passage	Nature	Atlantic storm	Pacific storm
July 10	Wave			July 16	Wave	X					
							X	July 13	ITCZ		
July 13	Wave			July 18	Wave			July 21	Wave		Hilary
		X		July 17	ITCZ			July 20	ITCZ		
		X ITCZ	X								
July 16	Wave			July 25	Wave			July 30	Wave		
		X ITCZ	X								
July 20	Wave			July 29	Wave			Aug. 2	Wave		Jewel
July 23	Wave			July 30	Wave	X					
							X	July 24	ITCZ		
		X ITCZ	X								
							X	July 28	ITCZ		Ilsa.
July 29	Wave			Aug. 3	Wave			Aug. 6	Wave		Dep.
July 31	Wave			Aug. 5	Wave			Aug. 8	Wave		
Aug. 3	Wave			Aug. 8	Wave			Aug. 11	Wave		
							X	Aug. 5	ITCZ		Katrina
		X ITCZ	X								
Aug. 7	Wave			Aug. 13	Wave			Aug. 17	Wave		
		X		Aug. 12	Wave			Aug. 15	Wave		
Aug. 10	Wave			Aug. 16	Wave			Aug. 19	Wave		
Aug. 11	Wave			Aug. 18	Wave			Aug. 21	Wave		
Aug. 13	ITCZ			Aug. 19	Dep.			Aug. 23	Dep.	Chloe	Monica
Aug. 15	Wave			Aug. 23	Dep.			Aug. 26	Wave	Doria	
Aug. 19	Wave			Aug. 25	Wave			Aug. 28	Wave		
Aug. 21	Wave			Aug. 27	Wave			Aug. 31	Wave		Nanette
Aug. 22	Wave		X								
Aug. 25	Wave			Aug. 30	Wave			Sept. 2	Wave		
Aug. 26	Wave			Sept. 1	Wave			Sept. 4	Wave	Dep.	
Aug. 28	Wave			Sept. 4	Wave	X					
Aug. 31	Wave			Sept. 6	Dep.			Sept. 9	Storm	Edith	
Sept. 3	Dep.			Sept. 11	Wave	X				Dep.	
							X	Sept. 15	ITCZ		
		X		Sept. 10	Wave	X					
Sept. 7	Wave			Sept. 14	Dep.			Sept. 18	Storm	Irene	Olivia
Sept. 10	Dep.			Sept. 17	Wave			Sept. 21	Wave	Dep.	
Sept. 14	Wave			Sept. 22	Wave			Sept. 25	Wave		
		X ITCZ	X								
		X		Sept. 20	ITCZ	X					
Sept. 17	Wave		X								
Sept. 18	Dep.			Sept. 24	Dep.			Sep. 28	Wave	Janice	
Sept. 20	Wave			Sept. 28	Wave	X					
							X	Sept. 23	ITCZ		
		X ITCZ	X								
Sept. 22	Wave			Oct. 1	Wave			Oct. 4	Wave		Priscilla
Sept. 25	Wave			Oct. 2	Wave			Oct. 5	Wave	Dep.	
Sept. 28	Wave			Oct. 7	Wave			Oct. 9	Wave		
							X	Oct. 1	ITCZ		
		X		Oct. 4	ITCZ	X					
Sept. 30	Wave			Oct. 9	Wave			Oct. 12	Wave		
Oct. 2	Wave			Oct. 10	Wave	X					
Oct. 6	Wave			Oct. 12	Wave			Oct. 16	Wave		Dep.
Oct. 8	Wave			Oct. 16	Storm	X				Kristy	
Oct. 12	Wave			Oct. 18	Wave			Oct. 22	Wave		
Oct. 12	Wave			Oct. 18	Wave			Oct. 22	Wave		
		X ITCZ	X								
Oct. 14	Wave			Oct. 23	Wave			Oct. 27	Wave		
Oct. 18	Wave		X								
							X	Oct. 20	ITCZ		Dep.
Oct. 21	Wave			Oct. 26	Wave			Nov. 11	Wave		
		X		Oct. 25	Wave	X					
Oct. 24	Wave		X								
							X	Oct. 24	ITCZ		Ramona
Oct. 26	Wave			Nov. 1	Wave						
Oct. 29	ITCZ		X								
							X	Nov. 4	ITCZ		
							X	Nov. 14	Dep.	Laura	
		X		Nov. 16	ITCZ	X					

Table 2.—*Summary of 1971 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	Subtropical Atlantic	Caribbean	Gulf of Mexico	Total
Waves	49	4	–	2	–	55
ITCZ	4	15	–	15	–	34
Depressions	3	–(4)	7(1)	–(2)	4(2)	14(9)
Named storms	0	–(1)	–(6)	–(4)	–(1)	–(12)
Totals	56	19(5)	7(7)	17(6)	4(3)	103(21)

number of disturbances emerging from Africa are of the ITCZ type. This should not significantly change the total number of African disturbances because this value is based entirely on pressure and wind indications over western Africa at coastal stations.

2. CENSUS OF 1971 TROPICAL SYSTEMS

The year 1971 featured 103 independent systems, 23 depressions, and 12 named storms. The results of the census are tabulated in tables 1 and 2 and shown schematically in figure 1. Table 1 presents pertinent information describing the history of 92 of the 103 systems, giving the dates when systems passed three key stations—Dakar, Senegal; Barbados; and San Andrés Island. The other 11 systems were either depressions or storms that formed in the Gulf of Mexico or over the waters of the subtropical Atlantic Ocean.

Table 2 summarizes the systems according to type and geographical area of formation. The numbers in parentheses indicates systems that were counted in a weaker stage of development. For example, of the six depressions that formed in the Gulf of Mexico (four plus the two in parentheses), two were spawned from tropical waves whose origin was in Africa. One of the depressions strengthened and became hurricane Fern. This is shown in the table by the number (1) within the parentheses. Over half of the systems originated in Africa and over half were wave type. This observation has been true in every one of the past 5 yr.

Figure 1 gives the number of systems that passed Dakar, Barbados, and San Andrés Island as well as the number that maintained their identity while crossing the Atlantic and Caribbean. Of the 56 African systems, 47 were tracked to the Caribbean and 38, all the way to the Pacific Ocean. Nine weakened in the central Atlantic. Ten disturbances were identified along the ITCZ in the Atlantic and were followed for at least 48 hr before dissipating. Another nine disturbances developed within the Atlantic and moved into the Caribbean. Fifty-six systems passed through the Antilles, 41 of which maintained their status while traversing the Caribbean. These 41 combined with the 17 that developed over the Caribbean resulting in 58 systems moving into Central America.

The depression tracks for the months June through November are shown in figure 2. The first depression of the year did not develop until July 4. Simpson and Hope

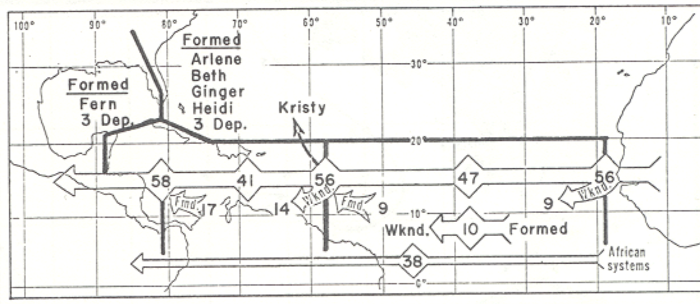

Figure 1.—Summary of the tropical systems that passed three key stations (Dakar, Barbados, and San Andrés) in 1971 and those maintaining their identity while crossing the Atlantic and Caribbean.

(1972) attribute the absence of depressions in June to above normal midtropospheric heights over the Gulf of Mexico, the Bahama Islands, and the southwestern Atlantic Ocean. Five depressions and one storm (Fern) formed in the Gulf of Mexico; one depression and four storms (Chloe, Edith, Irene, Laura) in the Caribbean Sea; four depressions and one storm (Janice) in the tropical Atlantic south of latitude 20°N; three depressions and six storms (Arlene, Beth, Doria, Ginger, Heidi, Kristy) in the subtropical Atlantic; and three depressions over Africa.

Even though the heart of the hurricane season (August and September) was unusually active, the geographical area of activity was abnormal. Over half of both the named storms (7 of 12) and depressions (14 of 23) formed in the subtropics near or north of latitude 25°N. We have been in a 4-yr period characterized by a significant decrease in tropical storm activity over the tropical portion of the Atlantic Ocean. The circulation features responsible for this trend are not readily apparent. In 1971, a very anomalous circulation pattern formed over the southwestern Atlantic and Gulf of Mexico during early September producing five depressions, three of which became named storms. The seed of this pattern was in the upper troposphere where a strong east-northeast to west-southwest-oriented trough developed and propagated downward to the surface in the form of an east–west shear line extending from the northern Gulf of Mexico nearly 2000 n./mi. eastward across Florida and the Bahama Islands into the Atlantic Ocean. As new impulses of energy were injected into the upper trough in the form of strong cold lows, depressions would form at the surface.

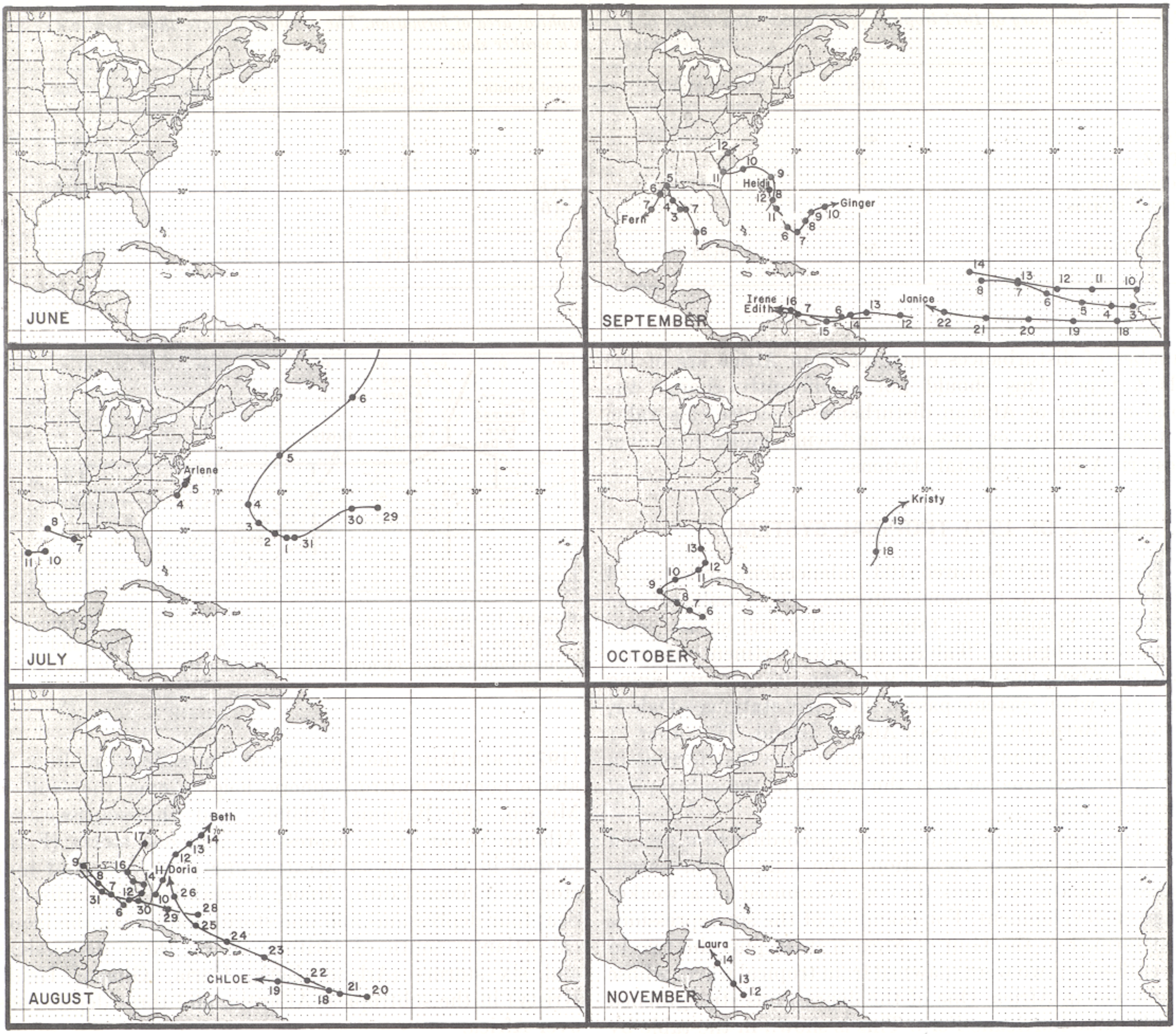

FIGURE 2.—Tracks of tropical depressions in 1971.

The surface map on September 11 (fig. 3) shows two of the depressions (one later became Heidi) and two storms (Fern and Ginger) spawned from this unusual circulation feature. In addition, two other depressions and tropical storm Edith were in existence on this day, marking September 11 as one of the most active days in recent years.

In conjunction with the large number of storms forming at unusually high latitudes, a greater percentage of the depressions and storms were spawned by disturbances of baroclinic origin. These two factors go hand in hand, and summers characterized by intense upper lows in the subtropics generally feature a large number of subtropical depressions and hurricanes.

Table 3 presents a summary of the type of seedlings that grew to depressions and storms in 1971. The seedlings have been grouped into two main categories, "tropical" and "baroclinic," depending on their source of energy; within each category there are two subdivisions. The tropical category includes those seedlings driven by latent heat. African systems have been placed in this group, although it is realized the driving mechanism is not clearly understood. A seedling has been labeled a disturbance if an enhanced area of convection persisted for at least 48 hr. It may or may not have been associated with the ITCZ. Baroclinic seedlings have been divided into two divisions; those which have their roots in the upper troposphere and those forming in conjunction with a baroclinic zone in the lower troposphere. Arlene offered a classical example of the latter process.

A cold front moved off the southeast coast of the United States on July 2, 1971, and became stationary. Overnight minimum temperatures revealed a temperature gradient of 2–3°C across the front. On July 3, satellite pictures (fig. 4) indicated the development of a frontal wave off the South Carolina coast. Figure 5 shows the

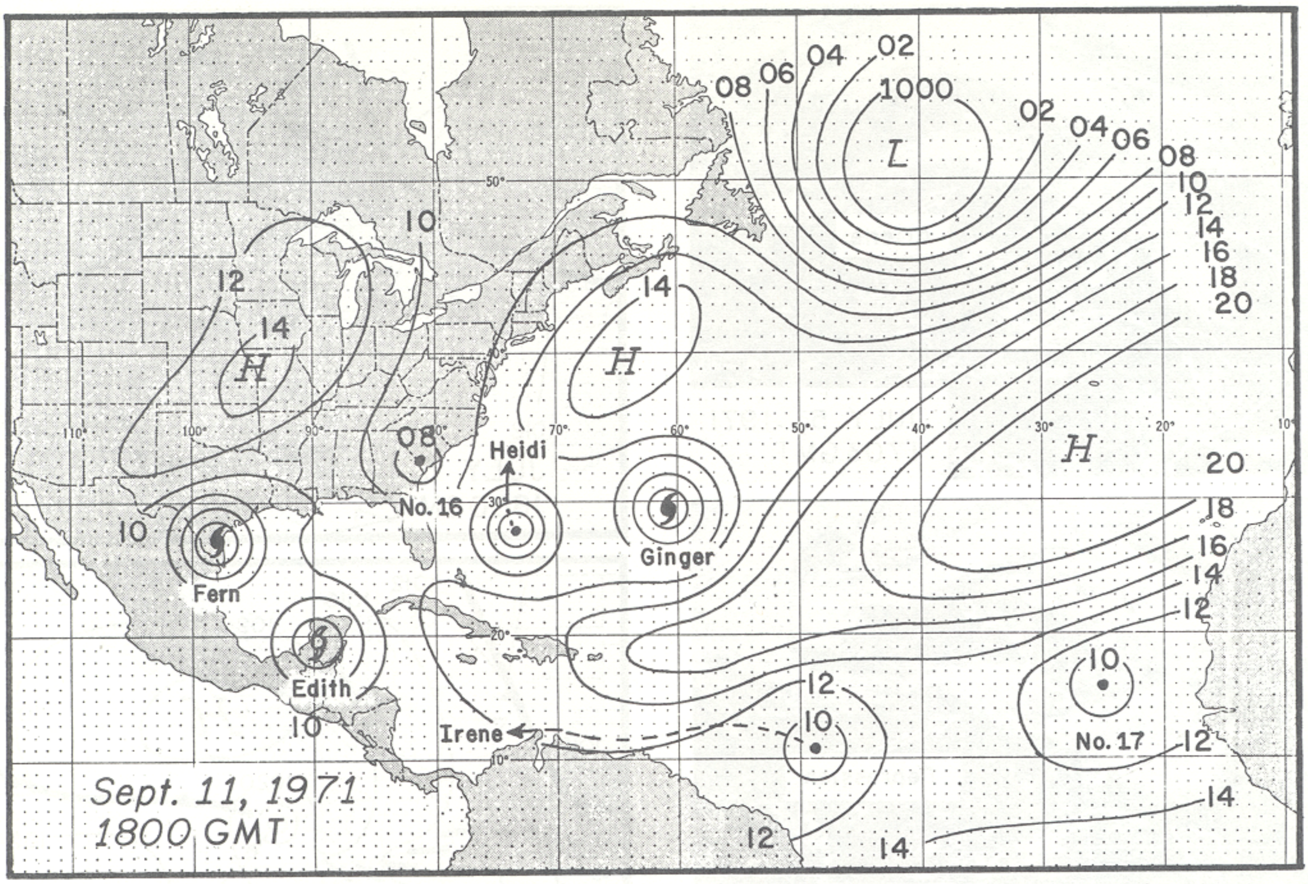

FIGURE 3.—Surface map for 1800 GMT, Sept. 11, 1971, showing four depressions and three named storms.

TABLE 3.—*Summary of the type of seedlings that initiated Atlantic depressions and named storms in 1971. The systems are listed under two main categories depending on their source of energy.*

	Tropical		Baroclinic		
	African systems	Disturbances	Upper troposphere	Lower troposphere	Totals
Named storms	6	1	3	2	12
Depressions	11	1	7	4	23

surface maps for 3 days during the period of development. The wave strengthened and moved toward the northeast, passing very near Cape Hatteras, N.C. The cloud pattern as viewed by the satellite on the 5th (fig. 4) was more circular, suggesting that the system was in a state of transition and becoming more tropical. This was confirmed later in the day when a reconnaissance plane found a warm core and winds in excess of the threshold value for a tropical storm. The suprising element in the development of Arlene was the rapidity of the transformation process.

Table 3 reveals that approximately half of the depressions (11 of 23) and 40 percent of the named storms (5 of 12) grew from baroclinic seedlings. This contrasts to the average for the previous 4 yr, which shows 20 percent of the named storms and 30 percent of the depressions coming from baroclinic systems.

Two of the depressions warrant special comment because they strengthened until they nearly satisfied the requirements for named storms. Each year one or more baroclinically initiated depressions strengthen and begin the metamorphosis process that leads to a warm core structure. During the transition stage, latent heat and baroclinic energies are released, and it is seldom possible to determine which source of energy is dominant because of data limitations. Spiegler (1971) discussed this type of system and Simpson and Pelissier (1971) suggested that they be called "neutercanes." The depression that developed east of Bermuda on July 29 was a hybrid type, and winds may have been near hurricane force when the Low approached the Maritime Provinces of Canada.

A second near-miss occurred in August when a depression began strengthening rapidly as its center approached Cedar Key, Fla. The depression formed southwest of Ft. Myers, Fla., on August 12, moved inland on the 13th, drifted slowly northward up the Florida peninsula on the 14th, and emerged back over the Gulf of Mexico north of Tampa on the 15th. Even though there was no evidence of intensification during the night at coastal stations, reconnaissance aircraft found 30-to 40-kt winds early on the 16th, and Cedar Key reported winds gusting to hurricane force for a brief period. Forecasters are consoled by the fact that advances in observing technology during the past 10–20 yr, including the evolution of radars and, more recently, satellites, eliminate the possibility of a major hurricane reaching the United States coast undetected; however, there is always the frightening chance of having a system intensify near the coast

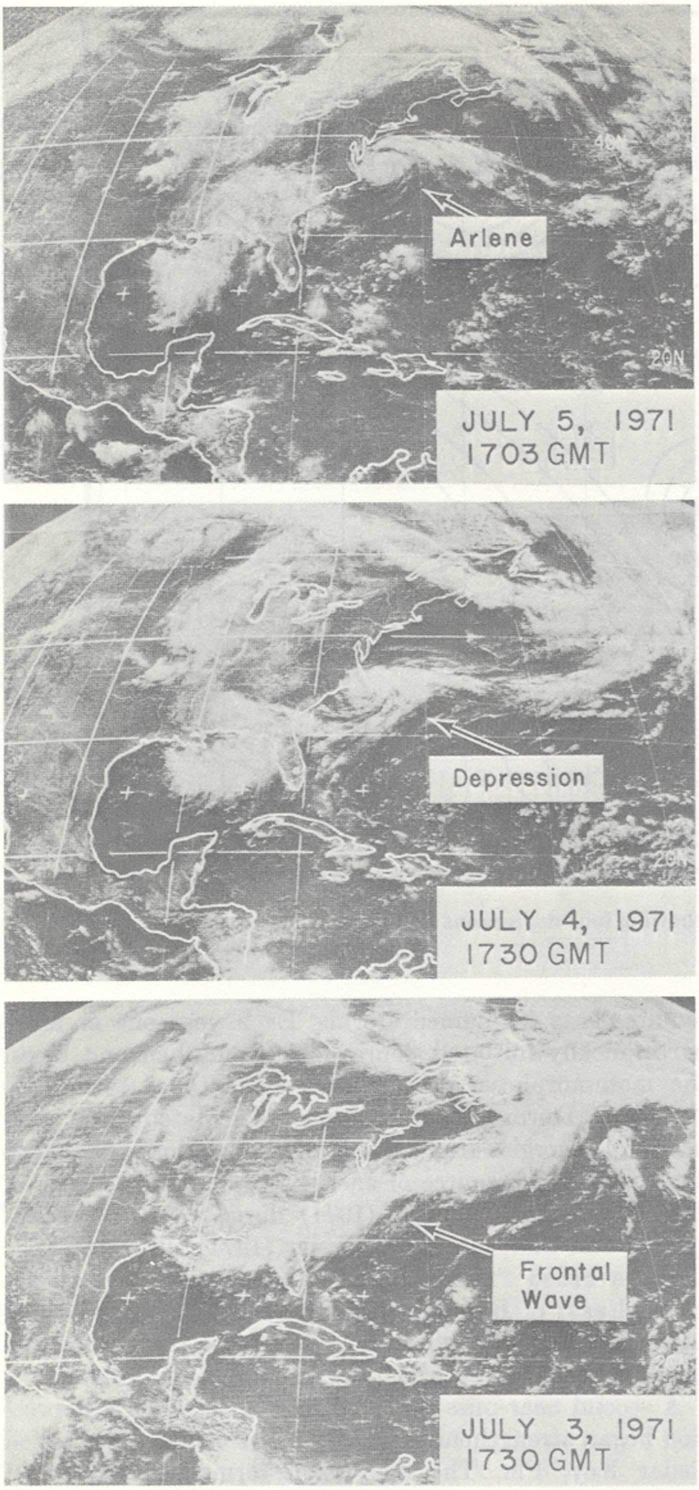

FIGURE 4.—Three-day sequence of Applications Technology Satellite pictures showing the development of Arlene.

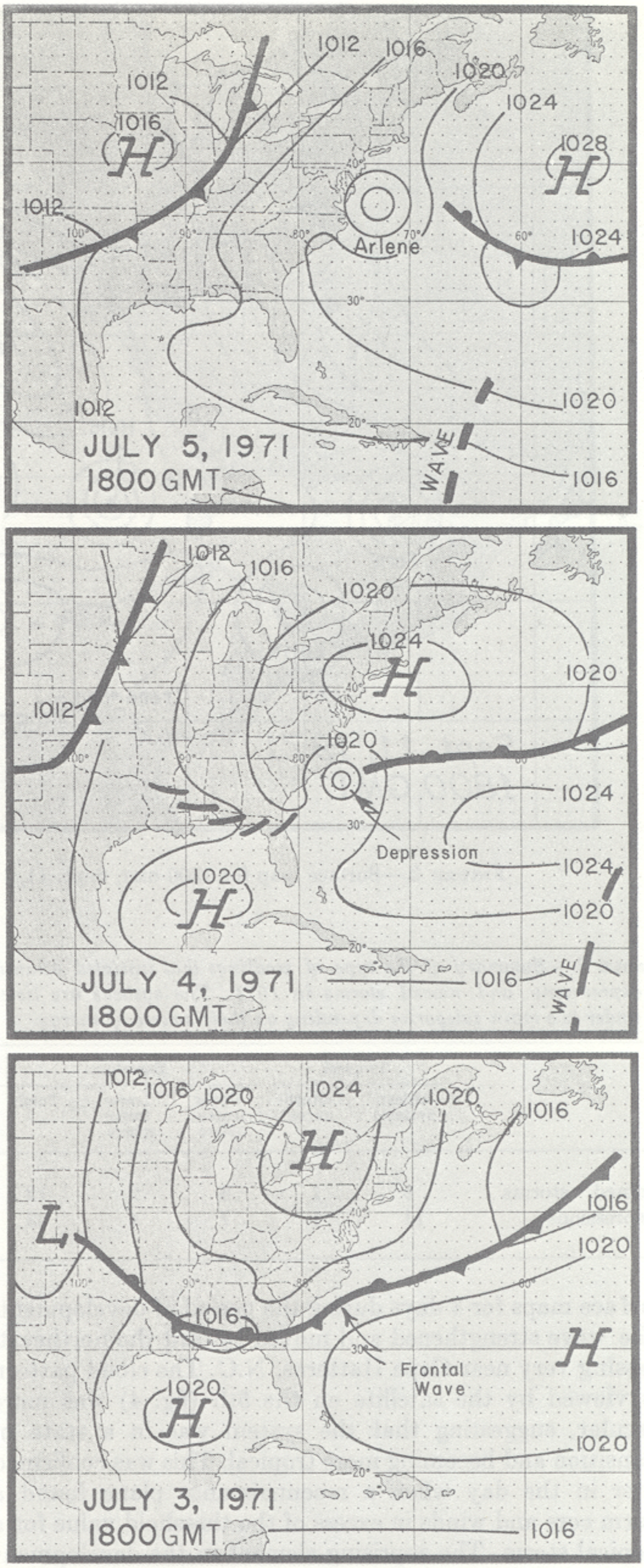

FIGURE 5.—Three-day sequence of surface maps showing the development of Arlene.

during the early hours of the morning when it is impossible to give advanced warning to coastal residents.

During the past 4 yr, we have attempted to relate the development of east Pacific storms to systems of Atlantic origin. Unfortunately, the lack of conventional data prevents a strong definitive position in some cases. San Andrés Island, located in the extreme western Caribbean, is the only reliable upper air reporting station that can be used to investigate this question. This means that unless disturbances are associated with recognizable cloud masses that allow satellites to establish the track, continuity must be maintained by extrapolating systems into the

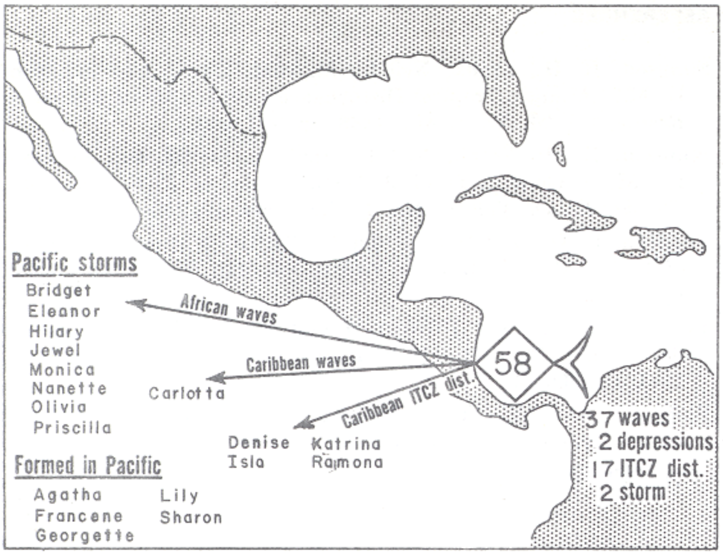

FIGURE 6.—Summary of the type of seedlings that initiated Pacific storms in 1971.

TABLE 4.—*Four-yr summary of the numbers of tropical systems within several categories*

	1968	1969	1970	1971	4-yr average
Total systems (all types)	107	105	85	103	100
Dakar systems	57	58	54	56	56
Barbados systems	59	44	53	56	53
San Andrés systems	40	43	45	58	46
Depressions	19	28	24	23	24
Named storms	7	13	7	12	10

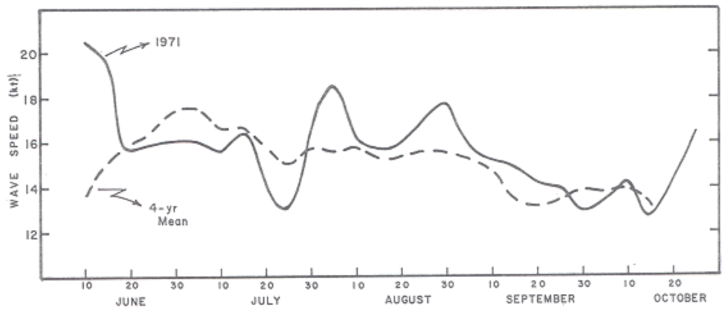

FIGURE 7.—Seasonal plot of the trans-Atlantic tropical wave speed for 1971 compared with the 4-yr mean.

Pacific with the speed that was observed in the western Caribbean. If the extrapolated positions eventually coincided with a developing area of convection on the ITCZ, the Atlantic perturbation was assumed to be the responsible agent. In no case was a disturbance carried on continuity beyond 3 days, and in most cases the extrapolated time period was only 1 or 2 days. The rationale for accepting this premise as a working hypothesis is that it conforms nicely with the Conditional Instability of the Second Kind (CISK) theory. CISK states that the vertical motion at the top of the boundary layer is directly proportional to the magnitude of the relative vorticity. Because wave disturbances are associated with positive vorticity, they provide a mechanism for enhancing convection.

The best example of a system maintaining its identity while crossing Central America in 1971 was the seedling that initiated Olivia. On September 7, a tropical wave emerged from Africa and started its journey across the Atlantic. A depression formed on the 11th near 11°N, 48.5°W and passed just south of Barbados on the 13th. Hugging the coast of South America, the depression experienced no significant change in strength until reaching the western Caribbean Sea, where winds increased and Irene was named. After moving inland, the remnants of Irene were easily followed across Nicaragua. Winds increased rapidly after the center moved into the Pacific Ocean and the system was redesignated by a new name, Olivia. Even though the evidence supporting the alleged continuity between Atlantic seedlings and Pacific storms is not as convincing as this in all cases, there is little doubt that Atlantic systems play an important role in east Pacific storm genesis.

The results for 1971 are shown in figure 6. Approximately two-thirds of the Pacific tropical storms were initiated by seedlings born on the Atlantic side of Central America, of which eight could be traced back to Africa.

3. COMPARISON WITH OTHER YEARS

Table 4 compares the storm totals in several categories for the past 4 yr with the average annual number (last column). Except for San Andrés systems, the storm totals for 1971 were very near the annual averages. However, one must use caution in using these annual averages because they are based on the past 4 yr, which have not been typical years. The reason for the sharp increase in the number of systems over the western Caribbean in 1971 is unknown but may be related to the anomalous circulation pattern that was established near this area in September.

The year 1971 was the fourth in succession that has been marked by a decrease in hurricane activity over the tropical Atlantic. Even though there was an abundant supply of storms and depressions in 1971, an unusually large percentage stemmed from subtropical baroclinic seedlings.

A new parameter is being introduced this year that we hope will eventually give us a better understanding of the hurricane problem as it relates to the large-scale circulation pattern. Historically, it has been difficult to determine anomalies in the broad-scale flow patterns over the tropical portions of the Atlantic Ocean because there have been no data. Inferences are generally based on extrapolation from midlatitude patterns and this is not very satisfactory. One of the parameters that we are able to compute from our data set is the average speed of disturbances as they cross the Atlantic from Africa to the Antilles and, heuristically, we believe this speed is directly related to the strength of the trades. Because the disturbance frequency is normally between 3 and 5 days, there are sufficient data to plot a seasonal curve of the wave speed. The seasonal plot was subjected to a 10-day running smoothing. A mean curve was then determined for the past 4 yr and is shown in figure 7 along with the curve for 1971.

During the first half of the 1971 season, the trade winds were weaker than normal. This was so until early August when the subtropical ridge shifted northward and strengthened, causing the trades to increase. The trades remained stronger than normal during August and September. Because there were very few storms in the Atlantic this year, this implies that the chance for hurricane genesis decreases in those years when the trades are abnormally strong and tropical waves move with an unusually fast forward speed. This also agrees with an old empirical forecast rule that states that fast-moving systems seldom strengthen.

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