THE HURRICANE SEASON OF 1963

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1. GENERAL SUMMARY

Nine tropical cyclones were observed in the Atlantic during the 1963 season and all but two were of hurricane intensity, although several were barely so. This is close to the normal number of ten which has been the average during the past three decades. Indeed, the storm of May 30–June 4 which developed in the southwestern Caribbean and resulted in heavy rains along the middle Atlantic coast as it moved northward was probably tropical during a portion of its history and might well have been included in the list. Also there were a number of tropical depressions which never reached storm intensity. The majority of the tropical cyclones developed initially between the Antilles and Africa but none attained hurricane intensity east of longitude 48° W. (fig. 1). The number of hurricane days greatly exceeded the average.

For the second consecutive year no major hurricane crossed the coastline of the continental United States. However, from the standpoint of loss of life this was the second most disastrous hurricane season of record in the Atlantic area as a whole, and will be long remembered in Cuba and Haiti.

The season started slowly with about the same pattern as in 1962: tropical cyclones developing in the mid-Atlantic and a strong east coast trough forcing early recurvature away from the United States mainland. For two years this persistent east coast trough has recurved every tropical cyclone forming in the Atlantic before it could reach the coast of the United States. In general, hurricanes continued weak and poorly organized. However, during August the planetary circulation began to change and September and October were very active hurricane months in the Tropics and subtropics.

In July in the middle troposphere, the east coast trough, especially from Hatteras southward, was stronger than normal and westerly winds at 500 mb. frequently prevailed as far south as latitude 25° N. At sea level in the Atlantic, the subtropical ridge was slightly west of, and about 5 mb. weaker than, normal near the Azores [1]. Tropical cyclone activity did not begin until the last day of the month.

While the east coast trough at 500 mb. in August strengthened north of latitude 35° N., it weakened over southern latitudes. At 700 mb., a mean negative height anomaly of 120 ft. was observed for the month near 20° N., 50° W., with a positive departure of 210 ft. near 42° N., 35° W., increasing the easterly flow over much of the tropical Atlantic. Tropical activity was almost normal, although both August hurricanes failed to reach major intensity.

In September at 700 mb., a strong positive height anomaly of 250 ft. was centered in the Atlantic near 40° N., 40° W. with negative departures extending throughout the Tropics and subtropics from the Gulf of Mexico (60 ft.) to 22° N., 5° E. (240 ft.), producing a much-above-normal easterly flow south of latitude 40° N. This synoptic situation is considered favorable for tropical cyclone formation and one was noted on the surface weather charts (with the exception of only two days) continuously from September 10 to October 30. For the first time in two years, one hurricane reached the coast of the United States, and two others threatened and to some extent affected the mainland.

Statistics on casualties and damage for the 1963 hurricane season are shown in table 1. As of January 5, 1964, final evaluation of these figures had not been completed in the Dominican Republic, Haiti, and Cuba.

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TABLE 1.—*Casualty and damage statistics, North Atlantic tropical cyclones, 1963*

Cyclone	Intensity	Date	Damage	Deaths	Injuries	Principal area affected
Arlene	Hurricane	July 31–Aug. 11	$300,000	0	0	Bermuda.
Beulah	do	Aug. 20–28	0	0	0	
Unnamed	Tropical storm	Sept. 10–15	0	0	0	
Cindy	Hurricane	Sept. 16–19	12,560,000	3	0	Texas-Louisiana.
Debra	do	Sept. 19–24	0	0	0	
Edith	do	Sept. 23–29	46,621,600	10	50	Lesser Antilles.
Flora	do	Sept. 20–Oct. 13	528,550,000	7,193	(*)	Haiti, Cuba.
Ginny	do	Oct. 16–30	400,000	7	0	Florida, North Carolina, Northeast.
Helena	Tropical storm	Oct. 25–29	500,000	5	14	Guadeloupe.
Total			588,931,600	7,218	(*)	

*Total unknown.

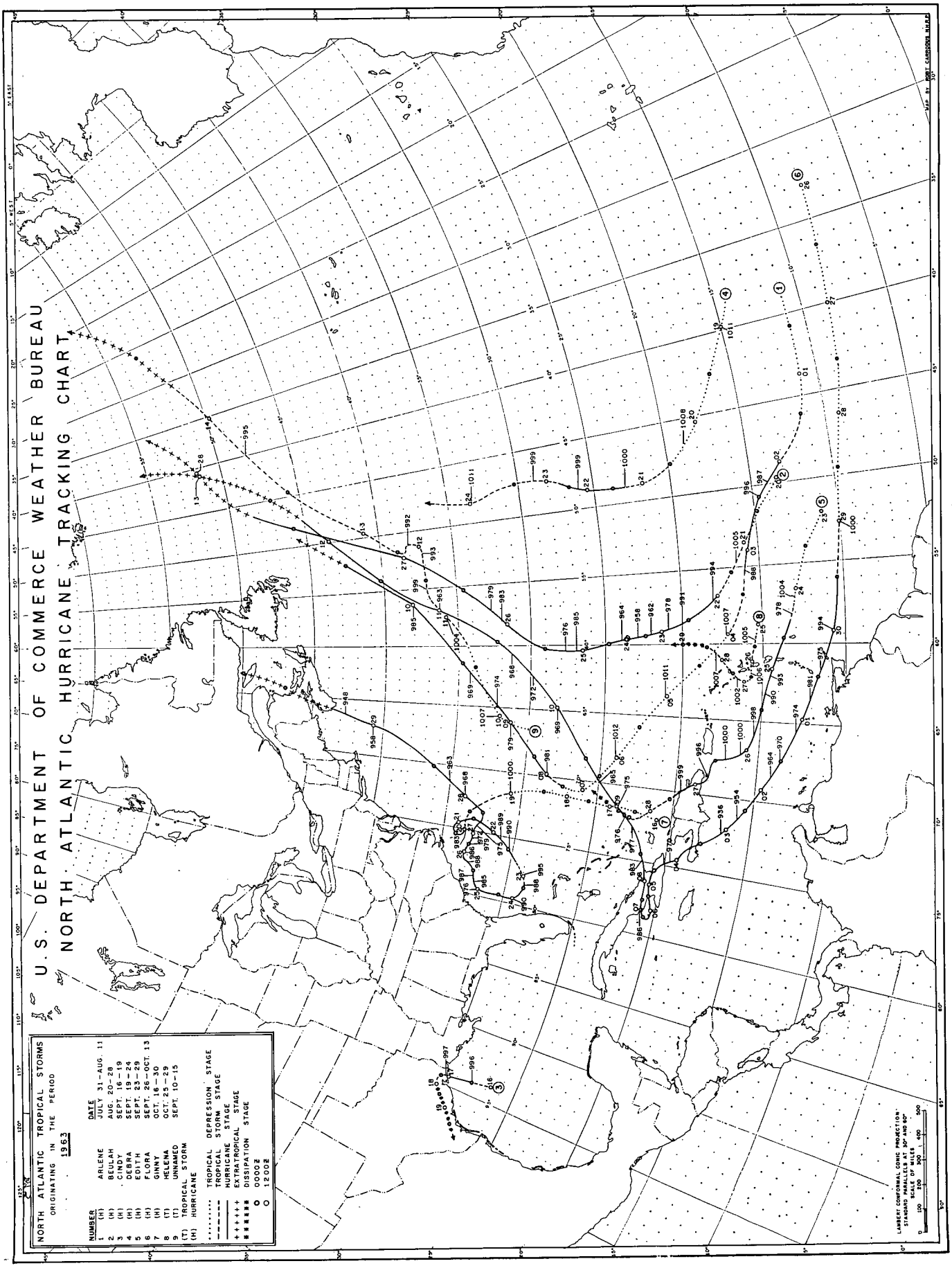

FIGURE 1.—Tracks of North Atlantic tropical storms in the 1963 season. Central pressure (mb.) is indicated along track.

2. INDIVIDUAL TROPICAL CYCLONES

Hurricane Arlene, July 31–August 11.—A cloud mass first detected in the mid-Atlantic by the TIROS VI satellite at 1505 GMT July 31, was undoubtedly Arlene in her embryonic tropical depression stage. Too far away then for immediate air reconnaissance, it was located by the Navy as a fully developed hurricane at 1642 GMT August 2 at 14.2° N., 49.8° W. During the preceding night the *Mormactrader* passed very close to Arlene. Although a complete ship's log is not available, an examination of her excellent 6-hourly reports indicates that the cyclone had just reached tropical storm intensity. It is estimated that Arlene intensified from storm to hurricane force within 12 hr., a rather rapid development. Three different flights which penetrated the cyclone during the next 26-hr. period reported hurricane-force winds. Based upon the surface pressures taken from the dropsondes, various pressure-wind graphs would support most of the hurricane-force winds reported by the aircraft. There is no doubt it was a well-developed hurricane, and was so described by the plane's meteorologist, yet rapid deterioration of the eye structure as well as a reduction of winds took place during the night of August 3–4 in an area where this rarely occurs, and by midday of the 4th Arlene was, at most, a tropical depression.

Tropical depression intensity was maintained through August 7, mainly, it is believed, as a reflection of a circulation aloft which seemed to persist throughout this degenerate stage, although at times the surface perturbation appeared to be nothing more than a disturbed area. Ship reports during the late evening of the 7th indicated that Arlene was once again a tropical storm and by 1357 GMT August 8, an Air Force plane penetrated the center. The eye was well defined and maximum surface winds were estimated at 75 m.p.h. A rather unusual type of fix and a very excellent one was obtained by radar from the *USS Lawrence* just prior to the Air Force plane penetration.

Except for an increase in forward speed, Arlene changed little during the night and early morning hours of August 8–9. The eye passed over Bermuda at 1600 GMT and observers there were able to obtain an eye sounding. Temperatures in the eye, at least in the lower and middle troposphere, were quite similar to those obtained in the eye of an October hurricane at Tampa in 1944 [2]. Temperatures at higher levels in the Bermuda sounding were considerably lower than in the Tampa sounding. As observed winds aloft indicate, the radiosonde did not remain within the eye throughout its flight.

There were no lives lost at Bermuda although there was $300,000 property damage. The lowest pressure was 28.78 in. or 974.5 mb., while rainfall was 2.69 in. Highest winds at Bermuda were from the east-southeast, 69 m.p.h., with gusts to 98 m.p.h., and tides were estimated at 4 ft. above normal.

After leaving Bermuda, Arlene moved on a northward course and probably increased slightly in intensity for a short while, only to weaken a bit on the 10th. During the night of August 10–11, it quickly lost tropical characteristics and merged with a polar front some 200 mi. southeast of Cape Race, Newfoundland.

There are some questions about Arlene which cannot be answered at this time. Why did it have so many changes in intensity while over water, and why did some of these occur over a relatively short period of time?

Most explanations for changes in intensity of tropical cyclones relate to the inflow-outflow mechanism at high levels as pointed out by Riehl [2] years ago. Indeed, data and subjective analyses at high levels around Arlene suggest that there was at times a good correlation between surface deepening and the outflow at the 200-mb. surface, as well as the intensity of the trough aloft during the weaker stages. However, if this relation is to be a good tool in forecasting, the pattern aloft must be antecedent to and not in association with the surface changes. Most forecasters feel that if the high-level charts are to be of any great value in the case of deepening, (a) the change in vorticity must be localized in just the right place, (b) the outflow should be into the westerlies, and (c) this feature must precede the surface change. These cannot be well demonstrated with Arlene's limited data. Data were insufficient to make a detailed analysis at 200 mb. at the time the sudden loss of intensity took place but it was obvious no outflow was taking place at 0000 GMT August 5.

Hurricane Beulah, August 20–28.—The circulation that developed into hurricane Beulah was located by aerial reconnaissance near 14° N., 51° W. about midday on August 20. Maximum winds were 35 m.p.h. in squalls and the lowest observed surface pressure was 1006 mb. or 29.71 in. Cloudiness and shower activity covered a large area. Surface ship reports during the preceding several days had indicated disturbed conditions over much of the area from the Cape Verdes westward to the longitude of the incipient storm. Data limitations preclude specification of the exact position of the Intertropical Convergence Zone during this period, but south and southwest winds of 23 to 30 m.p.h. were prevalent as much as 300 mi. to the north of the normal ITC position. Sparsity of data also makes the earlier history of the vortex obscure. Westward movement of about 11 m.p.h. would have brought a cloud mass photographed by TIROS VI near 13° N. 25° W. on August 14 to the vicinity of the developing circulation. However, it is not possible to say whether this represented the nascent stages of Beulah.

At 1200 GMT August 21, surface ships reported winds of 35 to 40 m.p.h. and when reconnaissance aircraft reached the area around noon, maximum winds were 52 m.p.h. with a minimum pressure of 1005 mb. (29.68 in.) at the center near 16.5° N., 54.5° W. The storm moved toward the west-northwest at about 10 m.p.h. and slowly intensified during the next 24 hr. On August 22, Navy reconnaissance reported that Beulah had in-

creased to hurricane intensity with a well-formed eye and central pressure 994 mb. or 29.35 in. Winds of 78 m.p.h. were observed just east of the center. A change to a more northwestward course which began during the afternoon removed any threat to the Leeward Islands. The highest swells at Sint Maarten, Netherlands West Indies, were 4 ft. over the open waters.

The hurricane began to deepen more rapidly late on the 22d and continued to intensify through the 23d. The lowest central pressure observed during the life of the storm was 958 mb. (28.29 in.) at 0630 GMT August 24. Radar showed an elliptical eye with a 20- to 30-mi. diameter. It is estimated that maximum winds at this time were about 120 m.p.h. During the late forenoon, aircraft penetrating the center indicated the beginning of a filling trend with an observed central pressure of 961 mb. or 28.38 in., and maximum winds of 115 m.p.h. The weakening stage, which persisted for the next 24 hr., was accompanied by an increase in the eye diameter to 60 mi. Maximum winds dropped to about 105 m.p.h. on the 25th.

Beulah moved at 5 to 10 m.p.h. toward the north-northwest during the 2-day period covering the marked deepening and subsequent filling, then turned to the north and began to accelerate. By the 26th, forward speed had increased to 23 m.p.h. or more toward the northeast. Under the influence of an upper trough off the United States east coast, the hurricane continued to accelerate and late on the 27th passed some 250 mi. east of Newfoundland, moving on a north-northeastward course at about 40 m.p.h. By 0400 GMT August 28, it was considered extratropical, a cold front having entered the circulation. However, maximum winds remained 70 m.p.h. or higher and when the low center reached the British Isles, on August 30, it was still accompanied by gales.

There was no loss of life or property damage attributable to hurricane Beulah.

One of the more interesting aspects of Beulah's history was the intensity variation from the 21st to 24th. During the initial deepening to hurricane intensity, the storm center was under the southwest quadrant of an upper-tropospheric anticyclone, a superposition which has been found statistically favorable to development. A cold trough in the westerlies moved eastward to the north of the storm on the 23d and 24th and mean flow charts for the layer from 37,000 to 42,000 ft. show that there was a breakdown of the portion of the anticyclonic cell to the north of the storm during this period of weakening. At the surface, a small parasitic circulation constituting a vorticity maximum was located some 300 mi. east of Beulah on August 22. This moved in a counterclockwise path at about 17 m.p.h. during the next 24 hr. It is difficult to track this feature subsequently but extrapolation would indicate that it also may have been a factor in the intensity variations since it would have moved very close to the more intense portion of the hurricane circulation around the 23d. Both of these sequences of events point up the difficulty in finding unique cause-and-effect relationships in changes in hurricane intensity but at the same time suggest some avenues for further studies.

A series of two cloud-seeding experiments was performed in hurricane Beulah on August 23 and 24, 1963, by Project Stormfury. The results have been described by Simpson, Malkus, and Eaton [3].

Tropical Storm (Unnamed), September 10–15.—Each year several storms occur which are not entirely tropical in character. Tropical cyclones derive their energy from latent heat of condensation while extratropical cyclones depend upon proper positioning of cold and warm air masses; i.e., cold air sinks and spreads under warm air causing air motion. At times "half-breed" cyclones develop over tropical oceans and tap both energy sources. In these cases it is difficult to decide whether a tropical cyclone name should be assigned to the Low. The Unnamed Storm in September was of this type, as was the late May—early June storm. It was not until a critical ship log was received after the hurricane season that the decision could be made to include the September storm in the official list.

Ship reports indicated a weak circulation north of Puerto Rico on September 8. The depression drifted slowly northward passing over Bermuda during the afternoon of the 10th. The pressure on Bermuda dropped to 1007 mb., or 29.74 in., and winds increased to 25 m.p.h. Tropical storm intensity was reached shortly before sunrise on the 11th. Maximum intensity occurred on the 12th when the *Freibury* experienced 78 m.p.h. winds, 27-ft. seas, and a pressure of 995 mb., or 29.39 in. The center remained small and tightly knit as the storm accelerated rapidly northeastward ahead of a cold front. Tropical characteristics were lost on September 14.

Hurricane Cindy, September 16–19.—Cindy, the first hurricane in the Gulf of Mexico in two years, formed in a trough of low pressure located about 200 mi. east-northeast of Brownsville, Tex., on the morning of September 16. Weather conditions had been highly disturbed in the southwestern Gulf on the 14th and 15th. Ship reports received around noon CST, indicated that the circulation was of tropical storm strength and was intensifying rapidly. By 2:00 p.m. the central eye was developed sufficiently to be located about 200 mi. east of Corpus Christi by the WSR–57 radar at Galveston. At the same hour, a report from the SS *Sabine* near the storm center indicated hurricane force winds, although there is some question whether the wind velocity recorder was read carefully. Cindy moved northward at an average speed of 8 m.p.h. during the afternoon and night of the 16th, remaining relatively small in area and with no further increase in intensity, although most of the circulation was still over the warm Gulf waters.

Winds and tides along the coast from the Galveston area eastward increased during the evening, with winds reaching maximum values during the early morning hours of the 17th. Over the Gulf, highest sustained winds were

estimated at 80 m.p.h. and highest gusts on the coast were 80 m.p.h., measured near the eastern tip of Galveston Island. The Weather Bureau Office at Galveston recorded a fastest mile at the rate of 50 m.p.h., and a peak gust of 74 m.p.h. on the 17th. In the Port Arthur area, the highest gusts were from 40 to 50 m.p.h., while in Louisiana gusts were estimated as high as 60 m.p.h. at Grand Chenier and 45 m.p.h. at Cameron, but were generally in the 25 to 35 m.p.h. range.

The central eye of Cindy, some 20 mi. in diameter, moved on shore around High Island, about midway between Galveston and Port Arthur. The Corps of Engineers there reported "light winds and near calm" between 7:30 and 11:00 a.m., CST, on the 17th and a low barometer reading of 29.44 in. (997 mb.) at 10:00 a.m. A slightly lower pressure, 29.41 in. (996 mb.), was recorded inland at Anahuac between 2:27 and 2:45 p.m.

The storm center became almost stationary for about 18 hr. shortly after moving inland, then drifted very slowly westward and southwestward with slowly decreasing intensity through the Texas Coastal Plain on September 18 and 19. This unusually slow movement during the decay of the storm resulted in an extended period of heavy rainfall in its northeastern sector over extreme southeastern Texas and southwestern Louisiana. Storm rainfall totals were 15 to 20 in. in portions of Jefferson, Newton, and Orange Counties, Texas and Calcasieu and Vermilion Parishes, Louisiana. The heaviest rain occurred at Deweyville, in southern Newton County: a 3-day total of 23.50 in., including 20.60 in. in 24 hr. between 7 a.m. CST, observations on September 17 and 18.

Storm totals were generally 4 to 8 in. in Louisiana as far east as Terrebonne Parish where Houma received 7.90 in. during the 15th–17th. Moist air pushed northward by Cindy's circulation brought significant rainfall, ranging up to 5 in. or more locally, to much of southwestern and central Oklahoma on September 16.

Since Cindy was a relatively small storm, barely of hurricane intensity, and developed near the coast, extremely high tides were not produced. Tides ranged generally from 3 to 5 ft. (mean sea level) along the upper Texas and western Louisiana coasts.

Property damage from wind was minor, consisting of roof damage to beach homes. Only minor flooding and some slight damage occurred from tides, but several roads were impassable for short periods, and waves destroyed several piers and caused some damage to boats.

Considerable damage was produced by the flooding of streams and drainage canals and ponding of water in the areas of extremely heavy rainfall over the lower Sabine Basin in both Texas and Louisiana. The flood waters were most severe in the Port Arthur-Port Acres area of Jefferson County. Water entered about 4000 homes in Jefferson, Orange, and Newton Counties, remaining in some areas for extended periods. Overall property damage—mainly from the flooding—was estimated at $11.7 million. Principal crop damage, estimated near $500,000 in Texas and $360,000 in Louisiana, was to unharvested rice. Fortunately most of the crop had already been combined, and rainfall in most areas was considered more beneficial than damaging to crops and ranges.

One man was drowned when he fell from a crew boat evacuating personnel from the offshore oil rigs south of Cameron, La., and two small twin sisters drowned at Port Acres on September 22 in the persistent flood waters still covering that section.

Hurricane Debra, September 19–24.—Hurricane Debra formed in the mid-tropical Atlantic and moved on a course well removed from any land areas. The first evidence of the circulation which later developed into Debra came from a ship report and a TIROS picture early on September 19. A reconnaissance aircraft was dispatched to investigate on the 20th and reached the southeast quadrant of the storm before being forced to return because of fuel limitation. The plane reported a radar eye and observed 30 m.p.h. west winds at the surface 20 mi. south of the center.

The next day, September 21, a second reconnaissance aircraft found 75 m.p.h. winds and a central pressure of about 1000 mb., or 29.53 in. Debra was at best barely a minimal hurricane for no more than 24 hr.

The storm continued northward slowly on the 22d with little change in intensity, then weakened and began accelerating on the 23d. It was finally absorbed by an extratropical Low on the 24th. There was no loss of life or property damage associated with Debra.

Hurricane Edith, September 23–29.—Hurricane Edith formed in the Atlantic east of the Lesser Antilles on September 24. Existence of a disturbance was first suspected when the Dutch tanker *Acteon* reported a south wind of 28 m.p.h. and surface pressure of 1010.1 mb. (29.83 in.) as it moved southward through the Intertropical Convergence Zone on September 22. Photographs taken by TIROS VII at 1156 GMT September 23, showed a vortex and extensive circulation area centered near 11° N., 52° W. A reconnaissance aircraft reached the area late that afternoon and found winds of 29 m.p.h. and a surface pressure of 1005 mb. (29.68 in.), but could see no definite spiral band pattern on radar. Early morning reconnaissance on the 24th found winds of 70 m.p.h., and a short time later Edith was reported to be of hurricane intensity with 80 m.p.h. winds. This location was some 120 mi. east of Barbados.

Edith passed over the north portion of St. Lucia between midnight and daybreak on the 25th and was at her maximum intensity at about this time. Lowest pressure computed in Edith was 978 mb., or 28.88 in., on September 24. The hurricane then moved on a general west-northwestward course to a point some 120 mi. south of Puerto Rico, and then turned to a more northwestward course passing over the eastern portion of the Dominican Republic before dissipating as it moved out north of Hispaniola.

Edith was weakened considerably by the mountains of the Lesser Antilles and was barely of hurricane intensity thereafter as it moved across the northeastern Caribbean and the Dominican Republic.

Martinique was heavily damaged, to the extent of $40 million, with 10 persons killed and 50 injured. Storm tides of 8 ft. above normal were noted. Fort de France reported a minimum pressure of 995 mb., or 29.38 in., with maximum winds of 127 m.p.h. Damage on Dominica was $2,611,600 and winds reached 80 m.p.h. in gusts. There was no loss of life there. On St. Lucia, 40 to 50 percent of the bananas were destroyed and the cocoa crop was a total loss. Tides there were 8 to 10 ft. above normal and Port Castries reported a dead calm beginning at 2 a.m. (EST) which lasted 75 min. Maximum winds were 90 m.p.h. There was no loss of life, but damage totaled $3,465,000.

On Barbados, winds reached 60 to 65 m.p.h. in squalls on the northern tip of the island and damage was estimated at $145,000. In the Dominican Republic damage was minor, but 50 to 60 m.p.h. winds along the south and southwestern coasts of Puerto Rico, together with heavy rains, caused $400,000 damage there.

Edith is another interesting case of a hurricane dissipating over tropical waters. About the time that Edith passed through the Lesser Antilles, a wave began to develop on a stationary front oriented east-west in the south Florida area. This frontal wave moved off east-northeastward with gradual deepening and by the time Edith reached eastern Hispaniola, the frontal Low was located some 600 n. mi. to its north with lowest pressure about 1005 mb., or 29.68 in. At the same time, another large surface Low was developing over the southwestern Gulf of Mexico. At 200 mb., a marked trough persisted over the Hispaniola area from the time that Edith was east of Barbados until the hurricane eventually moved almost directly underneath it on September 27. On the 28th as Edith was dissipating north of Hispaniola, the upper trough had flattened out into general easterly flow with no particularly well marked divergent or convergent pattern.

The frontal wave development moving across to the north of Edith weakened the pressure gradient markedly over and east of the Bahamas, thus lessening greatly the easterly low-level flow north of Edith and probably was a major factor in the storm's dissipation. As it moved out into an area of very flat pressure gradient and poor low-level inflow underneath a non-divergent pattern in the upper atmosphere, Edith was unable to recover from the distortion effects of the mountains of eastern Hispaniola.

Hurricane Flora, September 26–October 13.—At 8:50 a.m., EST, on September 26, the National Hurricane Center in Miami received an advisory from the Weather Bureau's National Weather Satellite Center stating that TIROS VII at 4:40 a.m., EST, had sighted a poorly organized vortex at approximately 11.5° N., 38.0° W., with a central overcast area about 4° in diameter with some banding to the north and east. Actually the TIROS satellite had sighted a complex cloud system with two principal areas of cloud concentration. The northern center mentioned in the advisory was probably associated with an upper-level vortex, and Flora eventually developed from the second cloud mass located at about 8.0° N., 32.5° W., which was associated with a very weak depression in the Intertropical Convergence Zone (ITC).

On the next day, September 27, TIROS VII photographed the same complex cloud system which retained a rather remarkable resemblance to that of the day before. The center of the southern cloud mass had moved to 8.0° N., 40.0° W. The cloud mass had grown somewhat in size but there were still no indications of spiral bands and apparently it was still associated with an ordinary depression in the ITC. TIROS was not in a position to photograph the cloud system on September 28 and 29 and there were not sufficient ship reports to indicate the existence of a circulation. However, on the 29th, the San Juan Hurricane Center requested surface observations from all ships in the area, and a Navy hurricane reconnaissance flight was arranged for daybreak on September 30.

A series of ship reports began to arrive early in the morning, September 30. A much delayed weather observation from the *Sinon* arrived around 3:30 a.m. EST. The report stated that the barometer at 5:30 p.m. the afternoon before had dipped to 1000 mb. (29.54 in.) with a wind shift from northwest to southwest, but nothing was said about the strength of the winds. The SS *Del Alba* forwarded an observation made at 1:00 a.m., EST, which arrived around 4:30 a.m., indicating winds from the northeast of 35 kt., and a barometer reading of 1006.8 mb. with a fall of 5 mb. in the past 3 hr. At 10:00 a.m., EST, much too late for adequate warning to Tobago, the *Del Alba* sent in a complete report as follows: "PASSED THROUGH STORM AREA COMMENCING 4 PM ON THE 29TH—PASSED NORTH OF CENTER 2 AM ON THE 30TH—ESTIMATED POSITION AT 6 AM 11.0 57.5—WINDS FROM THE NORTHWEST AT 4 PM TO NORTHEAST 28 MPH AT 10 PM TO EAST 40 MPH AT 2 AM—PRESENT POSITION AT 10 AM 10.9N 56.3W WIND EASTSOUTHEAST TO SOUTHEAST 16 MPH BAROMETER 29.94 INCHES RISING SOUTHEAST SEAS ROUGH WITH MODERATE HEAVY SWELL—HAVE PASSED STORM."

At 9:07 a.m., EST, the hurricane hunter plane reached the center of the storm, found a circular eye well defined, central pressure 994 mb., surface winds in excess of hurricane force, and the wall cloud around the eye 8 mi. wide. This observation indicated that hurricane Flora was the most concentrated and best organized tropical cyclone of the past two years. The San Juan Weather Bureau office issued a bulletin at 9 a.m., and the first formal hurricane advisory on Flora at 11 a.m., EST.

The eye of hurricane Flora passed over Tobago at 1:40 p.m., EST, with lowest pressure 28.77 in., 974 mb. (uncorrected), and maximum sustained winds 90 to 100 m.p.h. Seventeen persons were killed and crop and

property damage was around $30 million. On Trinidad, maximum winds were estimated at about 55 m.p.h. in extreme gusts from the southwest. There was only minor damage over most of Trinidad due to the protection afforded by the mountain range along the north coast. However, when the wind shifted to the southwest, many small boats in the harbor, which is an open roadstead to the west, were sunk. The large vessels had put out to sea.

At Northwest Point on the northern slope of the mountains, the marine reporting station estimated winds up to 70 m.p.h. with torrential rains. An amateur radio operator about 10 mi. east of Northwest Point and on the slope about ½ mi. from the shore, estimated the winds at 65 m.p.h. in gusts and zero visibility due to the heavy driving rain.

On Grenada damage was minor but six persons lost their lives by drowning.

After leaving the southern Windwards, hurricane Flora moved on a fairly smooth and regular track toward the southwestern Haitian peninsula gradually acquiring a more northward component. Flora intensified slowly until it began to deepen rapidly on October 3. At 11:20 a.m. EST, the Navy reconnaissance plane reported a central pressure of 936 mb., or 27.64 in. Flight level winds of 167 m.p.h. were measured on the 2d and about the same on the 3d. Probably some further intensification continued on the 3d until the center reached the coastline around 8 p.m., EST. At this time it was estimated sustained winds on the surface were around 140 m.p.h. with gusts 180–200 m.p.h. Thus at this time, Flora was comparable to hurricane Donna when it crossed the Florida Keys in 1960 and Carla when it reached the Texas coast in 1961.

The vortex entered the Haitian south coast at Côtes de Fer and calms were noted at Fond des Negrès and Anse à Veau. Winds of 102 m.p.h. were noted at Côtes de Fer at 7 p.m., EST October 3 and 120 m.p.h. at the Army base near Durez. The total rainfall at Miragoâne during the period when western Haiti was under the influence of Flora probably exceeded 75 in. On October 6–8 when Miragoâne was under the principal rain band feeding into Flora, the rain gage at the Reynolds Haitian Mines, Inc., which holds 19 in., was observed overflowing three times and was emptied. Thus at least 57 in. fell during this 3-day period. This does not include rainfall during the passage of the center nearby on October 3 and 4, or some rain which fell on the 5th.

Destruction over the mountainous terrain of the Haitian peninsula ranged from severe to complete. Flash floods washed away sections of many towns and land slides buried others. The height of the storm surge on the south shore is unknown but could easily have been 12 ft. or more. Crops were totally destroyed. About 3,500 bodies were counted and several thousand persons are missing. Of the missing, normally about half are eventually found to be casualties and half turn up sooner or later in some other locality. Therefore, an estimate of 5,000 deaths appears reasonable. Property and crop damage is estimated at $125 million with some reliable figures as high as $180 million.*

In the Dominican Republic, preliminary information indicates that damage, mostly from floods but to some extent from wind, to agriculture, livestock, communication lines, etc., is estimated at $60 million. There was also considerable damage to bridges and roads. In the western section of the Republic 10,000 km.^{2} were inundated. The known loss of life is 29 but is estimated in excess of 400. Floods were the most extensive of record, and several months after the storm roads were still impassable and communication channels in many western sections unrestored.

As Flora entered Cuba about 30 mi. east of Guantanamo Bay late on the forenoon of October 4, a warm High at sea level was located over Lake Huron. By the morning of the 6th, the High had reached Virginia and by the 7th, the southern Appalachian region. At about 20,000 ft. above the surface, which is often considered a representative steering level for hurricanes, the United States east coast trough which had been able to turn Arlene, Beulah, and Debbie northward east of the United States mainland, began to fill, and at the same time the westerlies began to retreat northward.

Earlier, on October 2 and 3, hurricane Flora had begun a gradual curve to a more northwestward course as it moved toward the southern coast of Hispaniola, and approached the long-wave trough position. During this same period, as an active short wave moved into the long-wave trough from the Great Lakes a fairly deep trough developed along the east coast of the United States and extended southward to the northern Bahamas by October 4.

Flora was still at a rather low latitude and the higher-latitude developments merely weakened the subtropical ridge and slowed the northwestward movement of Flora. By October 5, large height rises overspread all the eastern United States with the east coast trough weakening rapidly and moving eastward. The usual effect of rising heights north of a hurricane is a slowing and a turning toward a more westward course as the subtropical ridge intensifies. At the same time the usual outflow of warm air from a hurricane toward higher latitudes adds to the already increasing heights. In Flora, the 200-mb. pattern at this time indicated the main outflow was toward the east and east-northeast. This prevented any strong buildup of the subtropical ridge so that Flora's movement toward the west was very slow during the period October 5–7.

A rather weak, warm, 500-mb. anticyclone had persisted over the eastern Gulf of Mexico since the last of September. In conjunction with the buildup of heights over the eastern United States, this anticyclone became well defined by October 7 and halted further westward movement of Flora.

*Communication from Ralph Higgs, MIC, WBAS, San Juan, Puerto Rico.

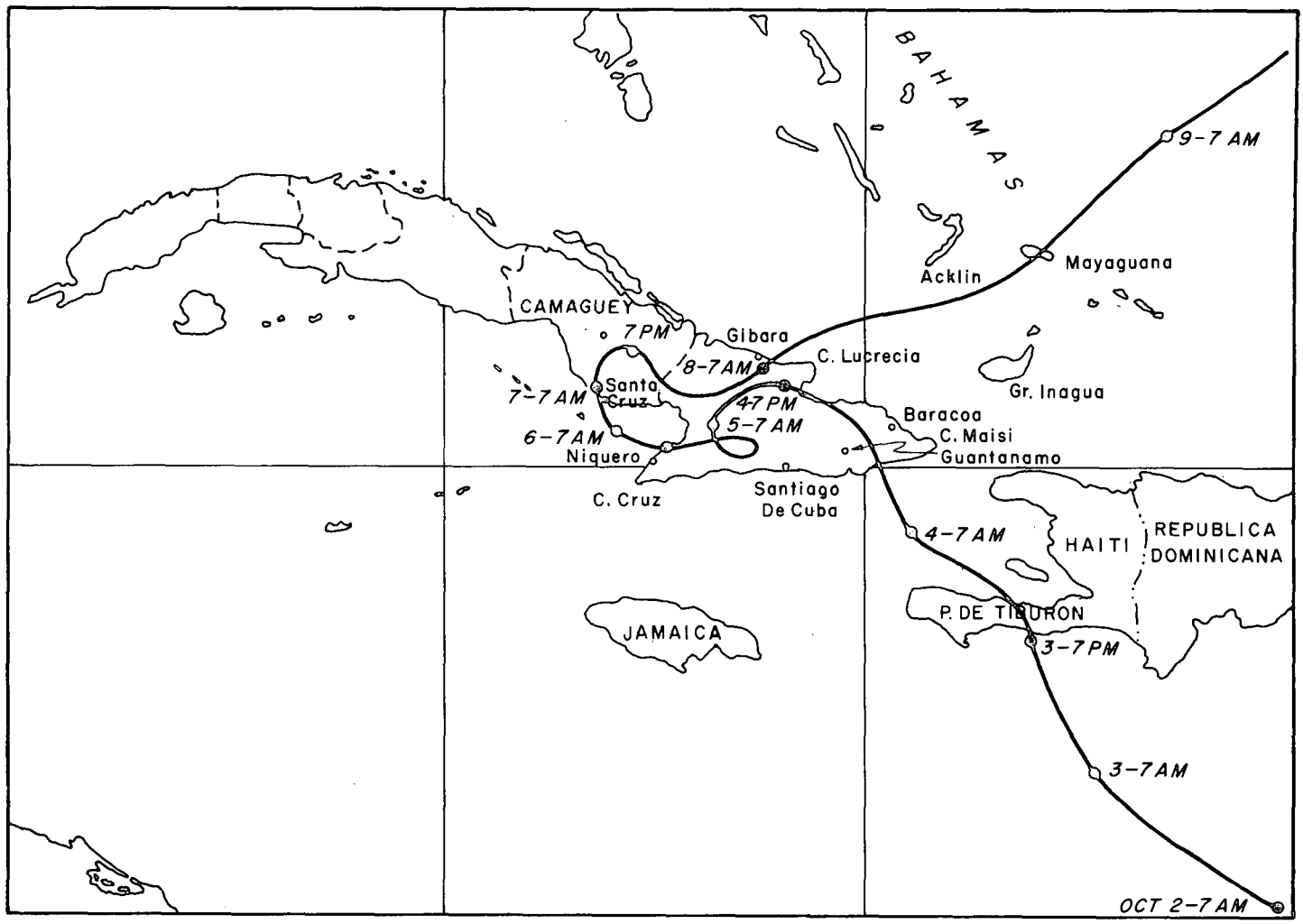

FIGURE 2.—Trajectory of hurricane Flora across Haiti and Cuba, October 2–9, 1963.

The weak trough at 500 mb., extending from near Bermuda to the eastern Bahamas, began to influence the hurricane after further westward movement was halted. During October 7 and 8 Flora moved slowly eastward to east-northeastward almost directly over the same portion of eastern Cuba it had traversed two days before. By October 8, another active short wave was moving into the long-wave trough position off the east coast and accelerating the southwesterly flow in the area of the hurricane. Thus Flora began to follow a more normal northeastward course at a gradually increasing forward speed into higher latitudes.

However, for portions of five days, completely boxed in by the high pressure areas to the west, the north, and the east, the hurricane meandered back and forth over eastern Cuba with winds of hurricane or near hurricane force and torrential rain. Members of the staff of the National Observatory at Havana jointly with personnel of the National Academy of Sciences (Cuba) carefully surveyed the hurricane area and on the basis of the survey

TABLE 2.—*Rainfall at some stations in eastern Cuba during hurricane Flora, October 3–8, 1963*

Climatological station	Rainfall (in.)	Geographical position					
		°	′	N.	°	′	W.
"Francisco"	41.89	20	48		77	35	
"Elia"	52.60	20	58		77	27	
"Manati"	42.03	21	19		76	57	
"Palma"	45.71	20	15		75	59	
"Alto Cedro"	45.35	20	34		75	57	
"Baguanos"	66.22	20	46		76	02	
"Boston"	47.68	20	54		75	44	
"Tacajo"	79.72	20	51		75	59	
"Preston"	41.26	20	46		75	40	
"Union"	42.09	20	13		75	51	
Santiago de Cuba	41.38	20	01		75	50	
Santiago de Cuba (Refinería)	64.84	--	--		--	--	
"Santa Ana"	64.21	20	16		75	54	

TABLE 3.—*Estimated casualties and damage, hurricane Flora*

Location	Killed	Damage
Tobago	24	$30,000,000
Trinidad		100,000
Grenada	6	25,000
Haiti	5,000	125,000,000
Dominican Republic	400+	60,000,000
Cuba	1,750	300,000,000
Jamaica	11	11,900,000
Bahamas	1	1,525,000
Florida	1	
Total	7,186	528,550,000

and hourly observations during the storm, determined the track as shown in figure 2.

Although Flora had not completely regained its former intensity by the time it entered Cuba, nevertheless winds of 70 to 100 m.p.h. lashed eastern Cuba for 100 hr. or more. Cuba's productive valleys and lowlands remained flooded for many days and crop damage was tremendous.

Rainfall amounts were enormous. Radio broadcasts from Cuba mentioned a total of 90 in. near Velasco. At Guantanamo Bay, the rainfall from hurricane Flora greatly exceeded the recorded amount for the entire year of 1962.

Dr. Luis Larragoiti Alonso, Director of the National Observatory, has forwarded rainfall accumulations in Cuba during the storm period as shown in table 2.

The last official announcement listed 1159 persons dead with more than 1000 persons missing. Applying the same estimating procedure as in Haiti, gives a death toll of at least 1750. No official estimate of crop and property damage is available so far. Based on reports emanating from Cuba, estimates of damage to the sugar crop range from 15 to 60 percent; to tobacco 15 to 50 percent; to coffee and cocoa 25 to 100 percent; and to rice 50 to 75 percent. There were heavy losses in cattle, poultry, vegetables, bananas, pineapples, and cotton, and extensive damage to factories, roads, and bridges. Estimates of total damage have ranged upward to $500 million, but at the present time it is believed $300 million is reasonably realistic.

Dr. Mario E. Rodriguez Ramirez [4], Chief of the Meteorological Division of the Civil Aviation Department of Cuba, lists three other prolonged Cuban hurricanes:

1851, August 19–21. Crossed the island from Oriente to Pinar del Rio.

1886, August 16–18. Took three days to travel from Oriente to Havana.

1910, October 13–17. Famous "huracan de cinco dias" which lashed the provinces of Pinar del Rio and La Havana.

Dr. José Carlos Millas* has recently discovered a prolonged hurricane which occurred during the last days of September 1616 and resulted in a great disaster around Bayamo similar to that caused by Flora.

While only peripheral effects were felt in Jamaica, there was considerable damage including: waterworks $420,000; bananas $5,600,000; other crops $1,400,000; roads and bridges $4,200,000; houses, etc. $280,000, or a total of $11,900,000. There were 11 fatalities mostly from flash floods. Some rainfall amounts are as follows: Palisadoes Airport 16.70 in.; Hope Gardens 14.11; Constant Spring 15.66; St. Georges College 18.38; Hermitage Dam 44.32; Hope Filter Plant 21.99; Seaview 31.94; Cavaliers 19.72; Jack's Hill 22.36. Gordon Town 35.00; Castleton Gardens 47.00; Cedar Valley 51.7; and Spring Hill 60.00 in.

Hurricane Flora passed through the southeastern Bahamas on the night of October 8. On Inagua, Flora was described as the "worst hurricane ever experienced there within living memory." Winds were estimated at 75 to 80 m.p.h. Two wharves were destroyed, the sea wall was damaged, and there was extensive damage to crops, roofs, and roads. The eye passed over Mayaguana shortly after midnight with maximum winds at 1:30 a.m. EST of 83 m.p.h. The sea wall was washed away and crop destruction was total. There was extensive damage to roofs and communication lines. One person was drowned.

Exuma, Long, Acklins, Crooked Islands, and Long Cay reported some damage to roads and property and crop damage ranged from moderate to total.

Flora is an historic hurricane—the second most deadly tropical cyclone ever to occur in the Atlantic area. The currently estimated total of 7,186 deaths considerably exceeds the death toll of the Galveston hurricane in 1900. Also, there are many small boats missing in the Caribbean with two to seven or more crewmen and passengers aboard each. These missing persons have not been included but may total 100 or more.

In the great hurricane which devastated the Windward and Leeward Islands from October 10–12, 1780, apparently over 20,000 persons perished; 4,326 on Barbados; 9,000 on Martinique; 4,500 on St. Eustatius; several thousand sailors in the Spanish, Dutch, British, and French Fleets; and a smaller number on other islands.

The estimate of some $528,550,000 damage to crops and property from Flora is conservative. There are, of course, indirect additional losses which will be incurred from loss of work, and long-period effects on crops which, in some cases, will materially lessen crop production for the next five to eight years. Since the time Columbus discovered the New World, no hurricane has dealt such a devastating blow to the countries of Haiti and Cuba.

Hurricane Ginny, October 16–30.—The depression which grew into hurricane Ginny developed in the southeastern Bahamas during October 16. Although there was a weak surface circulation at this time, there was a marked trough, surface and aloft, extending northeastward toward Bermuda, which represented a fracture from a polar trough. Consequently the trough was cold and the air mass baroclinic. In reality, the depression was not tropical and neither was the storm which developed later on the 19th. There was no warm core. Even though hurricane-force winds were observed on the 20th, it was not until the morning of the 22d that aircraft reconnaissance found a thermal structure that was more like a hurricane, rather than the late-season, hybrid type of the previous days. An eye of 20-mi. diameter had formed on the morning of the 22d; however, definition was reported poor.

During the 23d, some weakening of the hurricane occurred and there was probably a period of 10 hr. when the tropical cyclone was only of storm intensity. Ginny quickly returned to hurricane force and there were only minor variations in intensity during the remainder of its

*Formerly Chief, Cuban Meteorological Service, now retired in Miami.

life history although very slow intensification took place from this time until landfall was made on Nova Scotia on the 29th.

The track of Ginny was most unusual although not unique. Many hurricanes have looped and a few others have had rather long trajectories toward the southwest. The reader is referred to the "Yankee Storm" of October 30–November 8, 1935 [5], and to hurricane Able of May 15–24, 1951 [6]. It would seem that these two storms and Ginny certainly had an affinity for the warm Gulf Stream. Operationally, aside from the erratic track, Ginny was a most difficult hurricane in that a large part of its life history was uncomfortably close to land. For eight consecutive days while Ginny was meandering off the southeastern coast, the center was within 250 n. mi. of the United States mainland and during one day the wall cloud was less than 50 mi. from the Cape Canaveral-Daytona Beach, Fla. area. Indeed, considerable restraint was exercised in posting warnings. Hurricane warnings were in effect only from Charleston to Cape Fear and at Cape Hatteras at one time or another, and this represented about one-sixth of the coast that was threatened. Highest wind at any land station was 70 m.p.h., with gusts to 100, reported at Cape Fear at the Oak Island, N.C., observation point when the center took a temporary odd turn toward the North Carolina coast. Later the hurricane threatened New England but gale warnings which were in effect were ample. The fastest mile on the New England coast was 65 m.p.h. reported at Nantucket. The Coast Guard vessel *Cowslip*, off Portland, Maine, reported seas 30 to 40 ft. high and the anemometer broke at about 105 m.p.h. The lowest barometer reading was 28.98 in.

Ginny presented several major problems in analysis and forecasting. It is not clear just how the change from a cold cyclone to a warm core hurricane in a relatively short period of time came about. Conclusions might be made using sea surface temperatures or latent heat of condensation. While no computations have been made, it appears that the amount of heat transfer would fall short of that actually realized and observed. Ginny was a dry storm and latent heat would have been minimal. Proof of this was clearly indicated by radar. Nearly all echoes could be removed by only 18 decibels of attenuation, which shows that the precipitation was relatively light. Secondly, standard operating charts never clearly indicated a good outflow pattern at higher levels in the atmosphere, either before deepening or after. Thirdly, there were occasions, probably more than the average, when forecasting techniques failed. This was particularly true when the hurricane was making a loop or hairpin turn and the forecast methods (especially those with a large amount of persistence or extrapolation built in) carried the center forward.

TABLE 4.—*Data on Hurricane Ginny*

State	Maximum winds (m.p.h.)		Lowest pressure (in.)	Precipitation (in.)	Tide (ft.)	Damage (dollars)
	Sustained	Gusts				
Florida:						
Jacksonville	40			0.33		50,000. Beach erosion.
Daytona Beach	28	37	29.77	0.41	2–3 above normal.	Houses damaged at Boca Raton.
Georgia:						2500. Beach erosion.
Brunswick		30	29.82			
Savannah		30	29.82			
Outer Beaches	45					
Savannah Beach				1.30		
South Carolina:						3000.
Charleston City	42		29.83	3.25	6.3 MLW +2.7	
Ocean Dr. Beach	47			3.60		
Sullivan's Island		30	29.78	3.75		
Isle of Palms		45		5.02		
North Carolina:					3–4 above normal.	5000.
Wilmington	35	45	29.75	3.77		
Hatteras	35	45	29.61	5.36		
Oak Island	70	100	29.62			
Virginia:						Minor.
Norfolk	35	40	29.88	0.47	+1.6	
Connecticut:						Minor.
Bridgeport	35	52	29.53	0.13		
Rhode Island:						Minor.
Providence	33	45	29.39	1.60		
Block Island		55	29.38	1.44		
New York:						Minor.
New York City		39	29.54	0	+1.0	
Montauk Pt		61				
Massachusetts:						100,000.
Boston	40	46	29.40	1.17	10.7 MLW +1.8	
Nantucket	65	76	29.12	2.95		
New Hampshire						15,000.
Maine:						200,000+.
Portland	45	68	29.21	1.24		
Eastport		75				
Rockland		100				
East Boothbay			29.05			

Ginny was probably more beneficial than damaging, in that much needed rain fell along the Carolina coasts and in southeastern New England and Maine. In northern and central Maine 6 to 18 in. of snow occurred in the cold air which pushed southward on the west side of the hurricane center. Two persons apparently perished in the snow storm and there was one other fatality. Possibly four others were lost on the Tug *Otho*. Damage resulted from minor beach erosion and relatively small structural loss to boats, houses, autos, etc., mainly in Maine and on Cape Cod. Total damage in the United States probably did not exceed $400,000. According to reports, damage in the Canadian Maritime Provinces was confined to small boats and from minor flooding with no known deaths.

Tropical Storm Helena, October 25–29.—Tropical Storm Helena developed in an easterly wave a short distance east of the Lesser Antilles on October 25. An extensive cloud mass, apparently associated with the easterly wave, was observed by the TIROS satellite near 15° N., 55° W. on the previous day. Two ships in the disturbed area during the early afternoon of October 25 reported southerly winds of 32 and 40 kt. with continuous rain. A reconnaissance aircraft later in the day found similar conditions and a central pressure of 1005 mb., or 29.68 in. The system was described as ill-defined with no wall cloud but with squall bands in the eastern semicircle.

The storm intensified slightly as it moved west-northwestward but later weakened to below storm force after passing between Dominica and Guadeloupe. The 5000-ft. mountains of the islands evidently disrupted the poorly organized circulation.

During the night of the 26th, Helena became almost stationary then turned northward and intensified slightly the next day. Central pressure dropped to 1002 mb. (29.59 in.) and reconnaissance aircraft reported winds of 58 m.p.h. in squalls between Guadeloupe and Dominica. Most of the squalliness was confined to a small area in the eastern quadrant of the storm as the center moved northeastward from the vicinity of Antigua on the night of the 27th. During the next 24 hours the storm assumed a more northward course and gradually weakened. Reconnaissance aircraft on the 29th found only an area of squally weather with highest winds about 23 m.p.h.

Although Helena was never a well-defined storm, it caused considerable damage to small craft and roads in the Windward Islands. On Guadeloupe, five persons were reported dead, 500 homeless, and 14 seriously injured. A number of barges and fishing craft were sunk or seriously damaged. Total damage is estimated at no more than $500,000.

The failure of Helena to intensify further and the erratic movement and northward recurvature can be attributed in part to a weak surface low pressure trough which persisted from the Windward Islands northeastward during the storm's history. This hampered the development of a strong easterly flow north of the center and the storm eventually moved northward in the trough. Conditions in the middle and upper troposphere were also not favorable for intensification as the storm remained under the northeastern portion of a 200-mb. anticyclone centered over the eastern Caribbean. Deepening is observed more frequently under the southwestern quadrant of upper-level anticyclones. Hurricane Ginny, off the southeastern coast of the United States at the time, may have affected Helena indirectly. Pronounced westerly and northwesterly flow at the 500-mb. and higher levels overspread the area from south of Ginny to the Lesser Antilles on October 27, resulting in vertical shear which was believed to be unfavorable to further development of Helena.

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