# HURRICANES OF 1955

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## 1. GENERAL SUMMARY

There were 13 tropical storms in 1955, (fig. 9), of which 10 attained hurricane force, a number known to have been exceeded only once before when 11 hurricanes were recorded in 1950. This compares with a normal of about 9.2 tropical storms and 5 of hurricane intensity. In contrast to 1954, no hurricanes crossed the coastline north of Cape Hatteras and no hurricane winds were reported north of that point. No tropical storm of hurricane intensity affected any portion of the United States coastline along the Gulf of Mexico or in Florida for the second consecutive year. Only one hurricane has affected Florida since 1950 and it was of little consequence. However, similar hurricane-free periods have occurred before.

Namias and C. Dunn [1] have advanced a hypothesis for the above-normal frequency of hurricanes in 1955:

> . . . planetary wave forms over the North Atlantic evolved in a manner which the authors have come to associate with tropical storm formation. Thus in late July the ridge of the Azores upper level anticylcone thrust strongly northeastward into Europe, thereby introducing a northeasterly flow which, through vorticity flux, led to an anomalously sharp and deep trough extending along the Spanish and African coasts. It was probably at the base of this trough that Connie developed—its formation encouraged by the injection of cyclonic vorticity from the north and by associated vertical destabilization processes as discussed in an earlier report [2]. If this hypothesis is correct, the frequency of tropical storms of the Cape Verde type may well depend upon the degree of development or suppression of the protruding Azores ridge to the north.

It is interesting to note that Garriott [3] almost 50 years ago, with no upper air data, gave a strikingly similar explanation:

> Tropical storm development was exceptionally active in American waters during September 1906. In seeking the causes of this activity, we find an apparent contributory condition in the distribution of atmospheric pressure over the region of observation. In the West Indies and adjacent waters barometric pressure was unusually low, while in the more northern latitudes of the Atlantic, and more especially from the Azores over the British Isles, the barometer averaged above normal, and after the 17th was remarkably high. This arrangement of air pressure overlying the Atlantic naturally produced an unusually strong flow of air from the more northern latitudes toward the Tropics, and in this accelerated movement of air currents is found a recognized associated cause of tropical storm development.

The 1955 hurricanes showed a preferred area of development to the east of the Antilles and to some extent a grouping in their paths. The three hurricanes entering the United States all crossed the North Carolina coast within a 6-week period and three more crossed the Mexican coast within 150 miles of Tampico within a period of 25 days.

The hurricane season of 1955 was the most disastrous in history and for the second consecutive year broke all previous records for damage. Hurricane Diane was undoubtedly the greatest natural catastrophe in the history of the United States and earned the unenviable distinction of "the first billion dollar hurricane". While the Weather Bureau has conservatively estimated the direct damage from Diane at between $700,000,000 and $800,000,000, indirect losses of wages, business earnings, etc., would bring the total over one billion dollars. The total loss of life and damage from Atlantic hurricanes in 1955 is estimated by the Weather Bureau at 1,518 or more killed and $1,053,410,000 damage of which 218 fatalities and $889,310,000 occurred in the United States. The figures for total damage are admittedly incomplete. The latest United Press tabulation of damage at time of preparation of this article was $1,680,200,000 in the United States and $401,200,000 outside the United States, which adds up to a staggering total in excess of two billion dollars. The number of 1,518 or more killed in and outside the United States is the greatest since 1942 when the Weather Bureau began recording this datum.

## 2. INDIVIDUAL HURRICANES

The individual hurricanes of 1955 are summarized briefly and Connie, Diane, and Janet are discussed in some detail. For additional data, readers are referred to *Climatological Data, National Summary*, Annual 1955 (not yet released).

*Alice, December 30–January 5.*—A low pressure system of extra-tropical or tropical nature was noted some 600 miles northeast of the Leeward Islands on December 30, and on January 1 it reached hurricane intensity with definite tropical characteristics. It moved on a west-southwestward course passing through the Leeward Islands on January 2. An estimated wind of 75 m. p. h. was reported at St. Kitts and the last observation from St. Barthélemy indicated wind speeds ranging from 69 to 81 m. p. h. Winds of hurricane intensity were observed

at other points. On January 3 aircraft reconnaissance reported maximum winds of 86 m. p. h. and a dropsonde in the eye confirmed the warm-core center. After January 3, the hurricane diminished rapidly in intensity.

Mr. Ralph L. Higgs, Meteorologist in Charge at Weather Bureau Airport Station, San Juan, P. R., reports as follows:

This storm has aroused considerable interest. People were somewhat skeptical and slow in believing that a hurricane had actually formed. Already historians have expressed their opinion as to whether this was, or was not, the first of its kind in this area. In Puerto Rico a controversy centers about a storm that affected this island in the year 1816; one historian maintaining that it occurred in the month of January while another holds that it occurred in September. Reports from other islands mention a winter storm that affected the region many years ago. It appears that wintertime storms have been observed in these areas before. It is doubtful, however, whether any of them ever attained the intensity of "Alice" of 1955. It can be said of great certainty that this storm was definitely the first of its kind, at least, in the last 100 years.

The records do indicate, however, that a winter hurricane of somewhat similar origin passed through the Leeward Islands on March 8, 1908, with Basseterre, St. Kitts, reporting a minimum pressure of 29.28 inches. Columbus described several of the winter storms encountered by him on his journeys to the New World as "hurricanes". Brooks [4], however, has found they were probably normal winter storms. Occasional winter hurricanes do occur in the Pacific Ocean and tropical Lows are more rarely observed in the Atlantic, but it is most unusual for one of the latter to reach full hurricane intensity during the winter season. Possibly this may be another consequence of the general warming observed during the past several decades.

There was no loss of life from Alice and damage is estimated at around $100,000. The rainfall was beneficial in Puerto Rico where it alleviated a dry period which had persisted since the middle of the previous October.

*Brenda, July 31–August 2.*—Tropical storm Brenda formed in the north-central Gulf of Mexico on July 31 and crossed the coastline east of New Orleans on the afternoon of August 1. It was attended by rains of 4 inches or more from Pensacola westward to Lake Charles, and by winds of 50 m. p. h. at Shell Beach on the south side of Lake Borgne where the tide rose to 5 to 6 feet above normal. Two lives were lost in the Mobile area but total damage was small.

*Connie, August 3–13.*—Hurricane Connie set the stage for one of the most disastrous and costly floods of record in the northeastern States. The hurricane's slow movement on the 10th, 11th, and 12th resulted in heavy rainfall from North Carolina northward across the northeastern States to the interior of New England. The rains did not let up until the dying remnants of the hurricane had moved into the Great Lakes region on the 14th. The rainfall amounted to 2 to 8 inches in eastern North Carolina and ranged upward to 10 to 12 inches from the Chesapeake Bay area to extreme southern New York.

The first indications of hurricane Connie were noted on the morning of August 3 when the SS *Mormacreed* reported unusually strong westerly winds and showery, squally weather between Latitudes 5° and 10° N. and Longitudes 50° and 55° W. At the same time another ship, the *African Sun*, passed through a strong easterly wave in the vicinity of Latitude 16° N. and Longitude 45° W. The SS *Bonaire* reported a pressure of 996.2 mb. (29.42 inches) and a wind of east-northeast force 8 at 2200 EST of the 3d, providing the first indication that a strong vortex had formed in the northern end of the easterly wave. Earlier in the day, there were some indications of a vortex in the southern end but the principal cyclogenesis took place in the top end of the wave, as is usually the case, and hurricane Connie was born. The irregular Cape Verde reports provide no evidence of any unstable wave passing through the area in which Connie might later have developed. Reconnaissance aircraft on the 4th reported the eye at Latitude 15.8° N. and Longitude 52.8° W., with a false radar eye about 75 miles northeast of this position. Highest wind observed was 55 knots in the northeast quadrant. As it turned out, the false eye proved to be the real vortex which developed rapidly into hurricane Connie.

The storm moved west to west-northwest at 14 to 16 m. p. h., gradually increasing in size and intensity, and, by the morning of the 5th, maximum winds were estimated at 125 m. p. h. with a central pressure of 985 mb. (29.09 inches). The hurricane center passed some 40 to 50 miles north of the northern Leeward Islands and Puerto Rico, attended by gale winds with peak gusts of 80 to 100 m. p. h. and moderately heavy rains in the islands. On August 7 the eye was described by the observer as being shaped like an inverted cone, with the calm area less than 8 miles in diameter at the surface and 38 miles across at 18,000 feet. Maximum surface wind at this time was estimated at 145 m. p. h., and lowest pressure was 952 mb. (28.11 inches) measured by dropsonde. On the next day, the central pressure had diminished to 944 mb. (27.88 inches) the lowest during the life of the hurricane, as it moved northwestward some 200 to 250 miles east of the Bahama Islands. The hurricane slowed to 6 to 8 m. p. h. in forward speed 400 to 500 miles off the northeastern coast of Florida, and central pressure had filled to 954 mb. (28.17 inches) by the afternoon of the 9th, and to 977 mb. (28.85 inches) by the morning of the 10th. Penetration during the 10th indicated the eye was becoming filled with clouds and poorly defined. Connie drifted slowly toward the west-northwest and west on the 9th and 10th, turned toward the north on the night of the 10th, and north-northeast late on the 11th. It then turned northward again on the 12th as it passed inland on the North Carolina coast near Morehead City. At Wilmington, N. C., the fastest measured mile was 72 m. p. h., and the peak gust was 83 m. p. h. during the evening of the 11th as the hurricane passed about 100 miles to the southeast and east of the station. Winds

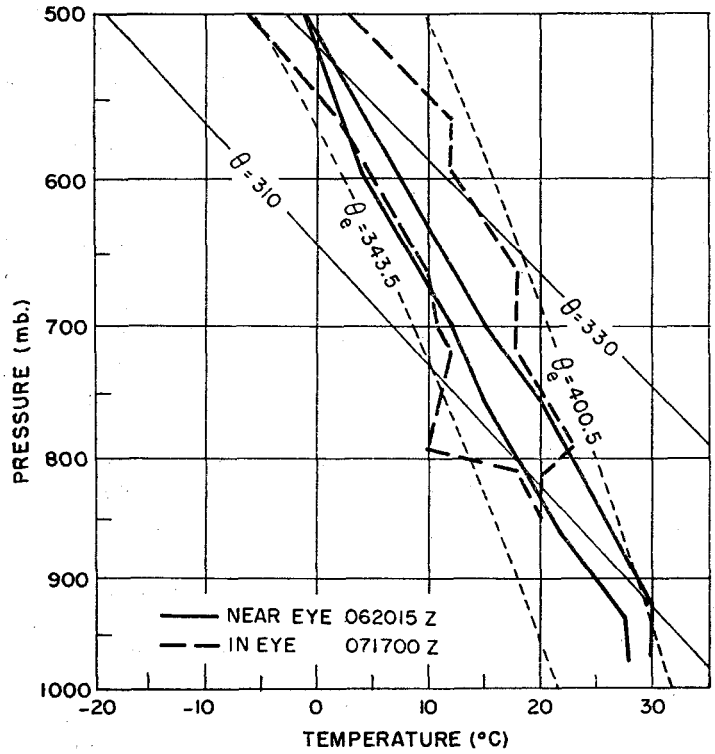


FIGURE 1.—Dropsondes in hurricane Connie, August 6 and 7, 1955.

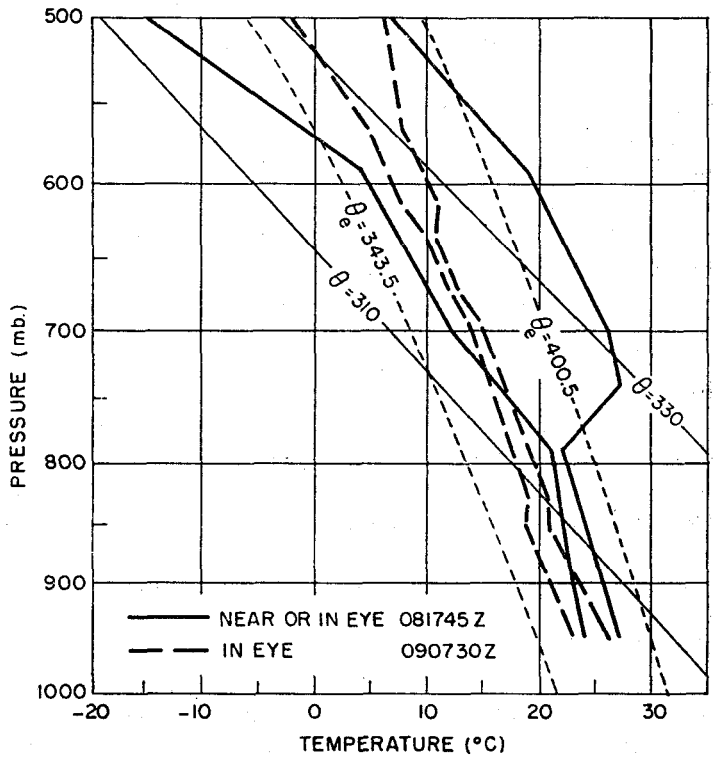


FIGURE 2.—Dropsondes in hurricane Connie, August 8 and 9, 1955.

of 75 m. p. h. with peak gusts of 100 m. p. h. and lowest pressure of 962 mb. (28.40 inches) were reported at Fort Macon, N. C., near the point where the hurricane crossed the coastline. However, it has not been established whether this was a measured or an estimated speed.

Tornadic activity was reported in the Carolinas during the afternoon and evening of August 10, while the hurricane was about due east of the Georgia coast, and before the winds had increased to strong along the Carolina coasts. One tornado occurred in North Carolina at Penderlea in northern Pender County and five others were reported in South Carolina from Georgetown northward. These tornadoes were reported as moving from east to west.

Beach erosion on the North Carolina coast was considerable, as tides rose to as much as 7 feet above normal from Southport to Nags Head, and to 5 to 8 feet above normal in the sounds at the mouths of the rivers. Total damage in North Carolina was estimated at $40 million, of which about three-fourths was crop damage. The hurricane caused no deaths or serious injuries in North Carolina.

The slow and somewhat meandering course of Connie and the loss of intensity while off the south Atlantic coast for a 48- to 72-hour period from late on the 8th to early on the 11th were the principal forecast problems during the life of the storm. Synoptically, on August 8, a strong (1027 mb.) surface high pressure system was located over the eastern Atlantic with a ridge extending to the middle Atlantic coast. At the 500-mb. level the picture was rather similar, with the ridge aloft along the Atlantic

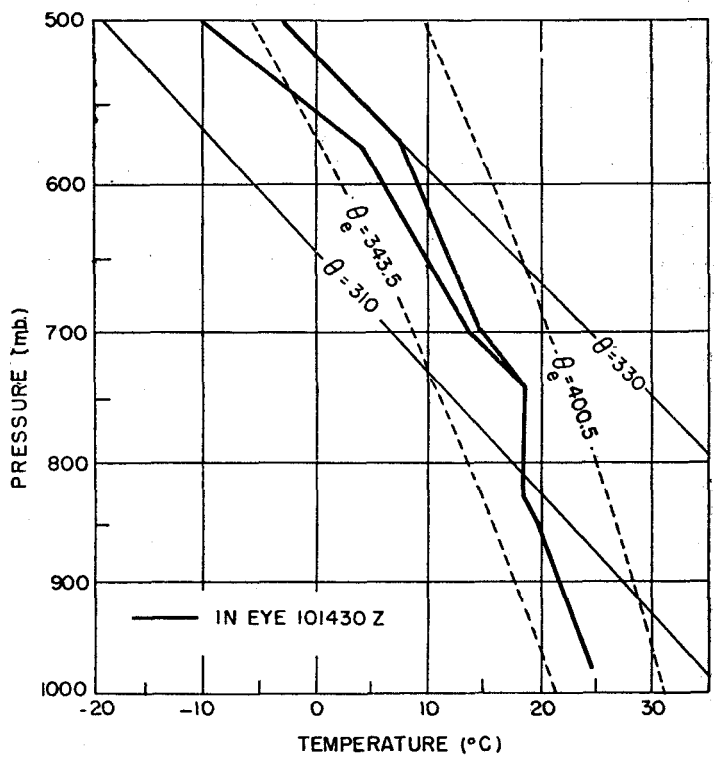


FIGURE 3.—Dropsonde in eye of hurricane Connie, August 10, 1955.

coast tending to move slowly northward with time. Several rather weak polar troughs moved eastward over northern latitudes with little effect in the latitude of and the area immediately to the north of the hurricane. The situation in the sub-Tropics was more complicated in the

middle and upper troposphere. A cold Low extended down below the 500-mb. surface and at the 500-mb. level moved from a position off the Georgia coast on the 6th southwestward into the central Gulf of Mexico by the 8th. Heights of the 500-mb. surface continued to build to the northeast of the dying hurricane as it progressed into the Middle Atlantic States and eventually into Michigan where it filled. Apparently during the period of slow movement, the average gradients on all sides of Connie were well balanced but tended to become progressively a little stronger on the east side and no polar trough extended sufficiently far south to materially disturb this balance.

Hurricane Diane was forming during this period and developing hurricane intensity. However, since Connie was larger and more intense, the "Fujiwhara effect" on it was slight, but what there was would exert some equatorward pull.

Soundings made in and near the hurricane eye showed the existence of a cold Low above Connie on the 6th (fig. 1). Another sounding around noon of the 7th indicated cooling had taken place up to 800 mb. and moderate warming and drying at higher altitudes (fig. 1). On the 8th, temperatures had risen at all levels and as much as 4° to 8° C. with further drying above 800 mb. (fig. 2). The hurricane reached its maximum intensity by the 8th. By early morning of the 9th, when the hurricane had slowed in forward speed and had begun to fill, slight cooling had taken place at all altitudes, and as much as 7° to 11° C. between 550 and 750 mb. (fig. 2). Additional cooling had occurred by the 10th, particularly above 600 mb. (fig. 3). Thus during the rather long period of slow movement off the Carolina coasts, filling was induced by cooler, and possibly to some extent, by drier air moving into the storm's circulation.

*Diane, August 10–19.*—The combination of large negative anomalies of surface pressure and 700-mb. height across the tropical Atlantic and positive anomalies at higher latitudes noted by Namias and C. Dunn [1] as prevailing from June through August was quite apparent at the time Diane was first detected. The Atlantic High, centered north of the Azores when Connie was in the formative stages, settled southwestward about 1000 miles during the next several days. It subsequently weakened as a minor trough passed to the north, was reinforced by the following High, and on August 10th was centered just east of Nova Scotia with the central pressure about 1028 mb.

There were some indications of a weak easterly wave earlier but the first conclusive evidence of the disturbance that was to become Diane was observed on August 10. Analysis that morning indicated a cyclonic circulation northeast of the Leeward Islands and at 1930 EST ships some 400 to 500 miles from the northernmost islands reported heavy showers and east to southeast winds of 35 to 45 m. p. h. At this time hurricane Connie was about 1200 miles to the west-northwest, just off the Georgia-South Carolina coast. On August 11 the first aircraft reconnaissance of Diane found the lowest pressure to be 1004 mb. (29.65 inches) with maximum winds 46 m. p. h., representing little or no wind increase from that shown by the ship observations 24 hours earlier. Clouds and rain extended in all directions from the pressure center with no variation of weather in the various quadrants. This early stage of growth was typical in the poorly defined eye and lack of organization.

During the night the storm curved abruptly from a northwest course and began moving toward the northeast, at the same time undergoing rapid intensification. The *MS Cobourg*, just west of the center on a parallel course to the northeast during part of the night, turned southward and eastward in evasive maneuvers early on the morning of the 12th. The intensification was so rapid that even though the ship was southeast of the center and the distance between it and the hurricane was increasing, the barometer continued to drop and the wind to increase, leading the crew to believe that the storm was looping back in their direction. The reconnaissance plane on the 12th reported that winds had increased to 125 m. p. h. and the central pressure was found to be 975 mb. (28.79 inches). The eye by this time was well defined and 30 miles in diameter. It was described by the observer as resembling an inverted teacup. The weather distribution had become more typical with the northeast quadrant showing more activity than the others. An interesting feature of the reconnaissance was a secondary pressure minimum, at first thought to be the principal center, located 62 miles northeast of the primary eye.

In view of the rapid growth, sudden change in direction, and multiple eye structure, it is interesting to speculate as to what extent factors other than strictly steering currents were involved in the storm's course at this stage. Possibly a process in which more rapid deepening was favored to the northeast of the storm than in other quadrants was partially responsible for the movement. It is likely that the original easterly wave began deepening as it moved under a cold Low (with super-imposed warm air at still higher levels) and that this condition provided added instability for growth and imposed the cyclonic flow of the large scale cold Low on the movement of the smaller warm vortex. Diane followed this cyclonic path (see fig. 9, August 11–13), until August 13 when it became re-established on a more normal west-northwestward course. By this time the developing storm had caused warming through a deep layer, resulting in a weakening of the cold Low and its influence on the hurricane's movement. The possibility of some influence from the "Fujiwhara effect", or tendency for cyclonic rotation of cyclone pairs about a point representing the center of mass, should also be considered here. Diane's erratic movement was at least in general agreement with this effect. A more normal path was resumed when Connie weakened and moved farther north. Once back on the west-north-

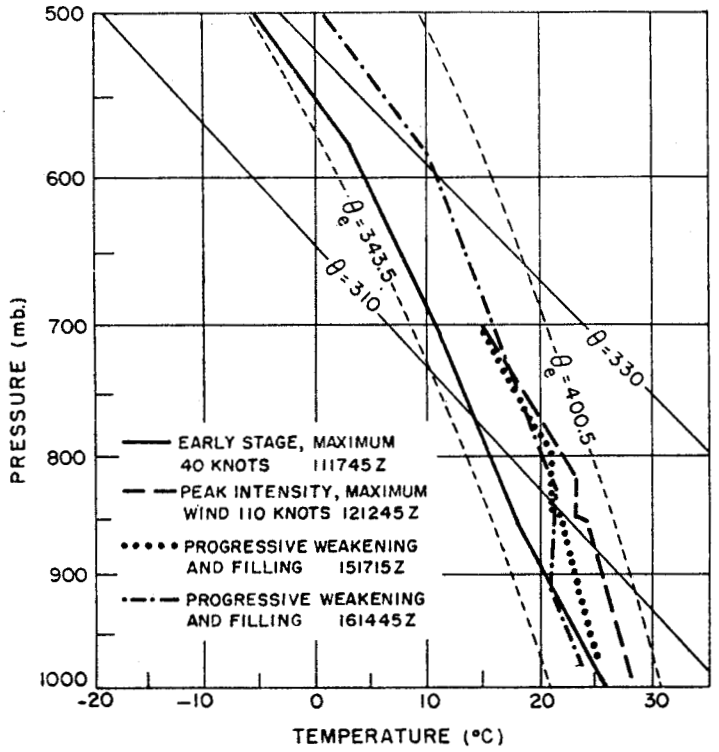


FIGURE 4.—Dropsondes in hurricane Diane, August 11, 12, 15, and 16, 1955.

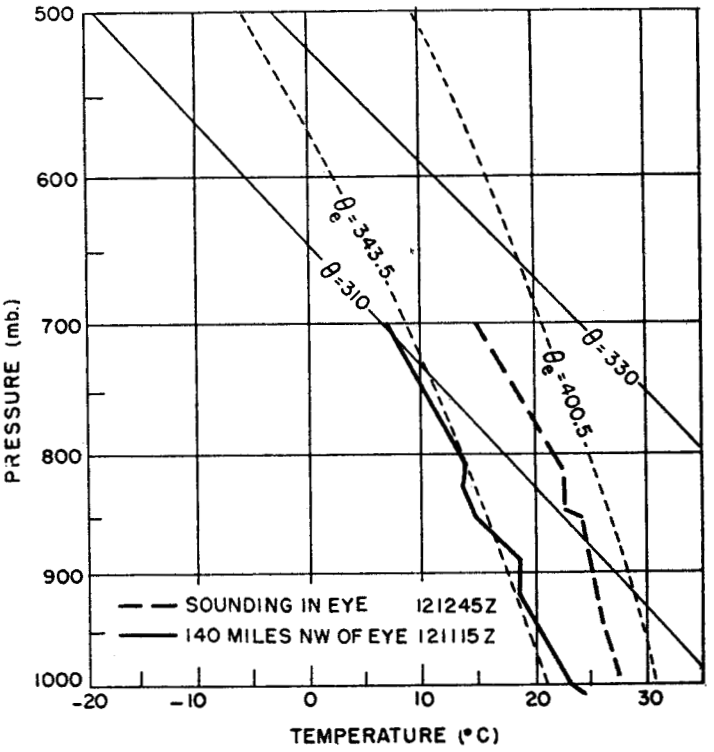


FIGURE 5.—Dropsonde in hurricane Diane, August 12, 1955.

west course, Diane continued to have a fairly regular movement, reaching the North Carolina coast on August 17.

A considerable number of dropsondes were taken during the life history of Diane, providing an excellent opportunity to observe changes in its thermal structure. (See fig. 4.) The first of these was taken on August 11 when development had only begun with maximum winds of 46 m. p. h. and minimum pressure 1004 mb. Some 24 hours later when winds had increased to 125 m. p. h. and minimum pressure had dropped to 975 mb., a dropsonde from 700 mb. showed a 24-hour temperature rise of 3° to 6° C. between that level and the surface. At this time another dropsonde 140 miles northwest of the center (fig. 5) showed temperatures up to 700 mb. to be within about 1° C. of the mean for a large number of soundings at that distance from the center of mature hurricanes (Jordan and Jordan [5]). The asymmetry evidenced in the pressure field by the multiple eyes was also apparent in the temperatures. Comparison of the sounding in the primary eye with one taken in the secondary center 62 miles to the northeast, showed the primary eye to be warmer by as much as 3° to 5° below 800 mb. but 1° colder at 700 mb., indicating greater instability in the dominant eye.

The lowest pressure measured in the storm was 969 mb. (28.62 inches) by dropsonde on August 13. Maximum winds were not measured on that date but 125 m. p. h. was reported on both the 12th and 14th. After the 13th a tendency for slight filling began and, coincidental with this, there was a gradual cooling of the layer below about 750 mb. This cooling amounted to about 2° C. by the 15th and ranged up to as much as 4° lower at 900 mb. on the 16th when compared with temperatures when the storm was at peak intensity (see fig. 4). On the 15th, the eye was reported as poorly defined and completely filled with clouds. Maximum winds were down to 86 m. p. h. on the 16th. When the center passed very close to Wilmington on the morning of the 17th, the highest sustained wind reported from any weather station was 50 m. p. h. at Hatteras, with gusts of 74 m. p. h. at Wilmington. It is estimated that winds of just about hurricane intensity were experienced at a few exposed points on the coast between Cape Hatteras and Cape Fear.

While some damage resulted from the storm tide and wave action along the coast, it was not extensive. The tide near Wilmington was reported as 6 to 8 feet above mean low water. Normal range between low and high tide is 3 to 4 feet in this area. No large departures from normal were reported elsewhere. As Diane moved inland and continued northward, the damage figures began to mount. Damage has been estimated at $754,706,000 of which $600,000,000 occurred in New England. These figures are admittedly incomplete and direct plus indirect damage would indicate that Diane earned the appelation of "the first billion dollar hurricane." Approximately 200 persons lost their lives, all from Diane's floods.

The sections worst hit were Pennsylvania, Massachusetts, Rhode Island, Connecticut, and southeastern New York, although there was some serious flooding from North Carolina northward. Much of the loss of life was due to the fact that relatively small river basins in the

northeastern States rose quickly when they received the outpour from the mountain streams and began flooding the valleys within a few hours. The torrential rains broke all existing records in many places. At Windsor Locks, Conn., 12.05 inches fell between 10 a.m., August 18 and 9 a.m., August 19. The previous record at Hartford, extending back 90 years, showed a 24-hour maximum of only 6.2 inches. A study of the heavy rainfall has been made by Mook [6], who showed by streamline analysis the advection of moisture-laden air into the area.

*Edith, August 24–31.*—Hurricane Edith formed on August 24 in an easterly wave and moved on a smooth parabolic curve passing well to the east of Bermuda on the 29th. Highest winds reported by reconnaissance were 90 m.p.h. on the 28th and 29th. The lowest pressure in the center was 991 mb. (29.26 inches) measured by dropsondes in the eye on the same dates.

*Tropical Storm of August 23–29.*—A weak circulation was observed near Grand Cayman on August 23. It moved on a northwestward course and gained intensity very slowly, passing between New Orleans Airport and the Naval Air Station about 0200 EST, August 27. The highest wind was 40 to 50 m.p.h. with lowest pressure 1000.3 mb. (29.54 inches). Only very minor damage was reported.

*Flora, September 3–9.*—An unstable easterly wave passed through the Cape Verde Islands during August 30–31. A message was received on the 30th from Panair du Brazil at Recife, Brazil:

> Tropical storm evident. Cyclonic circulation aloft to 4000 meters. Center approximately 11° N., 21° W. Displacement 18 m. p. h. WNW. Storm associated with easterly wave along ITC [intertropical convergence zone].

This weak circulation was the genesis of Flora which reached hurricane intensity on September 3 at approximately Latitude 21° N. and Longitude 40° W. Hurricane Flora moved on a smooth parabolic path northward through the middle Atlantic, passing some 9° east of Bermuda on the 6th and early on the 7th. The highest wind reported was 104 m.p.h. at 1230 EST on the 8th at Latitude 41.0° N. and Longitude 49.4° W., with central pressure of 972 mb. (28.70 inches). The lowest reported pressure during the storm's history was 967 mb. (28.55 inches) at 31.5° N. and 55.3° W. on the 6th.

*Gladys, September 4–7.*—This tropical storm formed in the Gulf of Campeche and moved first northwestward and later southward entering the coast of Mexico north of Tampico. Highest wind reported from Tampico was 48 m.p.h. from the northwest but higher winds may have occurred along the coast to the north of Tampico. The lowest pressure reported by reconnaissance was 997 mb. (29.44 inches). Winds of 81 m.p.h. were reported by the reconnaissance plane on one occasion and also by a civilian plane on the same date and, therefore, Gladys has been classified as of hurricane intensity. There was a fairly reliable report of 25 inches of rain in 3 days at Tampico beginning the sequence of hurricane-associated rains which culminated in the Tampico disaster. Meager reports indicate some deaths and damage along the Mexican coast.

At the same time an area of heavy squalls developed off the middle Texas coast on September 5 and moved inland on the 6th. Highest winds reported were 45 m. p. h. in the Corpus Christi-Port O'Connor area, and an oil rig 15 miles east of Port Aransas, Tex., reported gusts of 55 to 65 m. p. h. The Naval Air Station at Corpus Christi received 12.23 inches of rain in 24 hours and a high tide of 4.5 feet was reported in the Bay. Damage was estimated at $500,000 in the Corpus Christi area. It is reported that radar observations during this period indicated briefly the presence of a cyclonic circulation, consequently this may have been a separate tropical storm.

*Hilda, September 11–19.*—Hilda formed in an easterly wave and reached hurricane intensity at Latitude 20.0°N. and Longitude 69.1°W. on the 12th. It remained very small with a very narrow ring of strong winds around the eye for several days. It passed over the southeastern tip of Cuba where 4 persons were killed and there was moderate damage. By 1730 EST on the 15th, in the northwestern Caribbean, the central pressure had dropped to 963 mb. (28.44 inches). On the 16th, Hilda crossed the Yucatan peninsula midway between Chetumal and Cozumel, an area very sparsely populated.

Hilda reached its greatest intensity in the Gulf of Campeche. The center moved inland early on the 19th at Tampico which experienced a calm for 45 minutes. The lowest pressure at Tampico was 952 mb. (28.11 inches). Highest wind recorded before the anemometer blew away was 105 m. p. h. and the maximum wind was estimated at 150 m. p. h. Newspaper reports indicate 300 deaths and $120,000,000 damage, largely from floods.

*Ione, September 11–21.*—Ione developed in an easterly wave which passed through the Cape Verdes on September 6 and the circulation was still quite weak on the 11th; but Ione began to develop on this date and reached hurricane intensity during the night of September 14–15 in about Latitude 19.5°N. and Longitude 62.6°W. Ione then pursued a general northwesterly course toward the North Carolina coast. It reached greatest intensity on the 17th when a central pressure of 938 mb. (27.70 inches) was reported with maximum winds of 125 m. p. h. By the time the hurricane reached the North Carolina coastline on the 19th, the central pressure had filled to about 28.35 inches and the maximum winds had decreased slightly. Ione was the third hurricane to pass through eastern North Carolina within six weeks and the fourth within eleven months. Not within the known meteorological history of this section have so many hurricanes affected the area within so short a period. Total storm damage, mostly to crops in eastern North Carolina, is estimated at $88,035,000. There were 7 fatalities directly or indirectly attributable to the hurricane. The lack of any deaths from Connie and Diane in North Carolina and only 7 in Ione and the comparatively small property

damage, excluding crop damage, in this area, is a tribute to the effectiveness of the warnings and precautionary measures taken by governmental and private agencies such as the Red Cross.

After crossing the coastline, Ione recurved to the northeast passing out to sea south of Norfolk, Va.

*Janet, September 21–29.*—Most of the easterly waves in which hurricanes developed during the months of August and September could be traced back to the Cape Verde Islands. However, at about the time the easterly wave in which Janet eventually formed should have passed through the Cape Verdes, receipt of reports from this area was so irregular that no early history of the wave is available. Early on the 21st, pilot reports from the airlines Air France and Iberia indicated the presence of a weak tropical disturbance at about Latitude 13.5° N. and Longitude 53.0° W. It is the experience of the Miami Hurricane Center that almost all tropical storms of hurricane intensity, and the great majority of minor tropical storms as well, cannot pass across the New York-Capetown shipping route without detection. Apparently the wave was too weak to be noted between Longitudes 40° and 50° W. Therefore, it is believed that Janet was just attaining hurricane intensity when encountered by the *SS Mormacdale* in Latitude 13.6° N. and Longitude 55.2° W. at 1900 EST on September 21 when it reported winds of 63 m. p. h.

The eye of hurricane Janet passed just south of the island of Barbados shortly after 1100 EST on the 22d. It was an immature hurricane at this time with a very small ring of hurricane winds around the 20-mile eye. The reconnaissance plane reported the wall cloud around the eye only 5 miles wide but turbulence was very severe. Maximum winds were estimated by an observer on the south side of the island at 110 to 120 m. p. h., dropping off very rapidly 20 miles out from the edge of the eye. The rapid increase in winds is illustrated by the following observations taken at Evanman, Maxwells Court, Christ Church, by Mr. H. W. Webster.

| *Time* (AST) | *Speed* (*m. p. h.*) | *Direction* |
|---|---|---|
| 10:45 a. m. | 43 | |
| 11:00 a. m. | 58 | |
| 11:15 a. m. | 62 | |
| 11:20 a. m. | 64 | |
| 11:24 a. m. | 66 | Wind mostly north to north-northeast |
| 11:28 a. m. | 70 | |
| 11:37 a. m. | 72 | |
| 11:39 a. m. | 82 | |
| 11:40 a. m. | 90 | |
| 12:06 p. m. | 50 | East |
| Lowest barometer 29.20 inches, or 989 mb., sky brightening south, eye passing to south | | |
| 12:20 p. m. | 100+(110–120) | East-southeast |

No further data are available but the storm subsided quite rapidly.

The hurricane was moving at 11 m. p. h. at this time so it can be seen the ring of hurricane winds was very narrow. The lowest pressure reported by plane in the eye just to the south of the island was 979 mb. (28.91 inches). This was the first hurricane in Barbados in 57 years. The storm passed between Grenada and Carriacou early on the 23d. Fatalities in Barbados numbered 38 and in the Grenadines 122. Property damage was in excess of $2,800,000.

During the next several days in the eastern Caribbean, Janet pursued a course generally toward the west with some actual decrease in intensity. The center was located at 3:00 p. m. on September 23 at Latitude 13.2° N. and Longitude 64.8° W. with central pressure 996 mb. (29.41 inches) and wind 92 m. p. h., radar eye 40 miles in diameter, and wind eye 20 miles N–S, 27 E–W. Turbulence was moderate, sea high, no weather bands in northern semicircle but some in the southern semicircle.

During the early hours on the 24th, according to the Navy reconnaissance plane, Janet never presented good center definition and it is not certain the center was found. Weather targets consisted of large areas of diffuse targets with no spiral relationship. All center fixes were taken on strongest, most promising targets and the plane stated the fixes were of unknown accuracy. The radar bands were so disorganized, radar coverage was not considered feasible. Late in the afternoon, one very strong spiral weather band was found although the central pressure remained about the same. The reconnaissance plane reported:

> Eye centered Lat. 13.8° N. and Long. 69.9° W. at 3:02 p. m., EST, circular eye with well defined cloud and wind eye approximately 20 miles in diameter. Minimum pressure 29.38 inches, or 995 mb., maximum wind 127 m. p. h. . . . in weather band 40 miles from eye in southwest quadrant, wind shifted in weather band from 240° to 330°, band approximately 25 miles thick, section we went through showed up weakest on radar, maximum winds northwest through southwest 52 m. p. h., turbulence light to none except in weather band where it was moderate to heavy, precipitation light to none, navigation good, radar coverage not considered feasible for eye positions, however, weather band to west presents good picture.

On the 25th the eye was located at 1400 EST at Latitude 14.3° N. and Longitude 74.2° W. with a maximum wind of 98 m. p. h., central pressure 987.7 mb. (29.17 inches). The eye was described as well defined but there was evidence it was very changeable—hoop-shaped on one occasion, a figure "6" on another. One obtains the impression of a slowly but definitely intensifying storm. The reconnaissance flight on the night of September 25–26 summarizes its observations as follows:

> Eye completely closed circle after 9:15 p. m., average diameter 22 miles, storm presented symmetrical pattern of intense weather bands which extended 120 miles south, 140 east, 130 north, and 170 west, high overcast throughout area, low scattered to broken stratocu with tops near 6000, thunderstorms generally oriented in spiral bands throughout area, frequent lightning.

Rapid intensification was evident.

At 0830 EST of the 26th, Lt. Comdr. Windham with crew of 8 and 2 newspapermen reported in Latitude 15.4° N. and Longitude 78.2° W. that they were about to begin penetration of the main core of the storm. No further report was ever received from this plane. Janet had become a very severe hurricane.

The Navy reconnaissance plane at 1040 EST on the 27th reported the center at Latitude 16.9° N. and Longitude 82.7° W. with lowest pressure 938 mb. (27.70 inches), and maximum winds in excess of 115 m. p. h. by a large and uncalculable amount. Janet passed over Swan Island during midday with winds estimated at 200 m. p. h. The approach of the hurricane is described by the Swan Island weather reports as received at Miami:

0710E E16 ⊕TRW 047/77/76 NNE/2 PRESSURE DOWN 8 MBS LAST 3 HRS. RAINFALL LAST 6 HRS. 0.61

0745E E10⊕1/2 RQ 041 78/76 NE/14+28/SC MVG SW SEA ROUGH

0845E E10⊕RQ 027/78/77/NNE/25+30/PRESFR CLDS SC MVG SW SEA ROUGH

0945E E10⊕1/2 RQ 000/80/77/NNE/28+34/ PRESFR SEA VERY ROUGH

1000E E16⊕R 000/80/77/N/28 PRES DOWN 4.7 MBS LAST 3 HRS.

1030E GUSTS TO 38 MPH NOW. BIG COCONUT TREE JUST WENT DOWN IN FRONT OF LIVING QUARTERS.

1045E E10⊕1/2RQ 963/81/76/NNE/48+55/PRESFR

1100E WINDS NOW 60MPH WITH GUSTS TO 75 PRESSURE 29.065 INS.

1115E? ANTENNAS GOING DOWN NOT READING YOU AT ALL. ABANDONING STATION. ALL HANDS SEEKING SHELTER IN NAVY SEISMO BUILDING. WINDS NOW ESTIMATED IN EXCESS OF 100 MPH IN GUSTS.

From memory Mr. John Leban, observer, reported:

Around 1130 EST wind estimated over 120 m. p. h.

1215 EST wind estimated over 150 m. p. h.

1250 EST wind estimated 200 m. p. h.

1310 to 1335 EST eye wind 15 to 35 knots, pressure 938 mb. (27.70 inches) (from plane).

The vivid recollections of Mr. John Leban as the hurricane passed over Swan Island will be published in *Weatherwise* at a later date.

The hurricane center reached Corozal, British Honduras, and Chetumal, Mexico, about 1 a. m., local time, September 28. It was still a very concentrated storm with winds reaching hurricane force only about 2 hours before the arrival of the eye. In Corozal the barometer read 29.34 inches at 2300 EST and 27.10 inches at 0110 EST, falling 2.24 inches in 2 hours and 10 minutes with most of the fall occurring after 2330 EST. The official minimum barometer reading in Corozal was 27.10 inches (aneroid) and another aneroid in the house of a clergyman read 27.05 inches. In Chetumal the radio operator of the Mexican Aviation Company read 920.1 mb. (27.17 inches) on the mercurial barometer some minutes before the eye arrived. The original barograph trace (fig. 6) at Chetumal was furnished by Mr. S. B. Lizama Frias, Flight Dispatch Superintendent, CIA, Mexicana de Aviation,

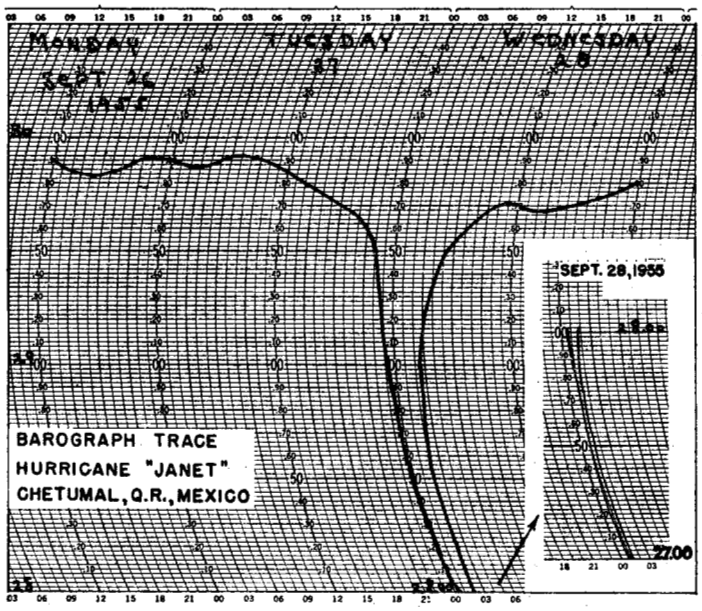


FIGURE 6.—Barograph trace, hurricane Janet, Chetumal, Q. R. Mexico, Sept. 26–28. Portion below 27.94 inches was constructed from a reliable barometer reading of 27.00 inches and the apparent diameter of the eye. (See text.)

S. A. The pen passed off the trace at 27.94 inches. A barometer reading of 27.00 inches in the eye at Chetumal was forwarded by Mr. D. N. A. Fairweather, the meteorological observer at Corozal. Corozal was in the southern edge of the eye and since the eye passed directly over Chetumal, it is believed the reading of 27.00 inches can be accepted. Therefore on the inset in figure 6 we have constructed a continuation of the trace below 28.00 inches based on this reading and the length of the period of calm at Chetumal. The lowest reliable sea level land barometer readings of record in the world are:

| | | |
|---|---|---|
| Lower Metacumbe Key, Fla. | September 2, 1935 | 26.35 inches |
| Basilan, P. I. | September 25, 1905 | 26.85 inches |
| Cossack, Australia | January 7, 1881 | 27.00 inches |
| Chetumal, Mexico | September 28, 1955 | 27.00 inches |

The anemometer at the airport terminal building at Chetumal registered 152 knots or 175 m. p. h. before it collapsed. The wind continued to increase and the maximum is estimated in excess of 200 m. p. h.

In British Honduras 16 persons were killed and total damage is estimated at about $5,000,000. In Chetumal, a town of about 2,500 people, only 4 badly battered buildings were left standing. Sea water reached a height of 6½ feet some 1,600 feet inland. The area is rather well protected from the Caribbean Sea by a sizable peninsula but there was one report of a hurricane wave south of Corozal. In Chetumal approximately 120 bodies were found in and about the ruins but the sea dragged away an unknown number. Altogether in the Mexican state of Quintana Roo, the death toll is estimated at about 500 with $40,000,000 damage.

Hurricane Janet passed into the Gulf of Campeche and

moved inland between Veracruz and Nautla. The circulation aloft continued its westward movement across Mexico and a squally disturbed area developed off the west coast of Mexico under this circulation late on the first of October. Floods were already occurring in the Tampico area from the rains of Gladys and Hilda when the torrential rains of this hurricane were added. Little information is available on fatalities and damage which should be attributed to Janet in this area, but according to the Weather Bureau Office at New Orleans, the floods in the Tampico area from the tropical storms of 1955 were probably one of the greatest natural disasters ever to occur in that country.

*Tropical Storm of October 10–14.*—A small vortex apparently developed in an easterly wave which passed through the Cape Verde islands on October 4. It was first reported by two ships on October 10 at approximately Latitude 28.5° N. and Longitude 42.8° W. The storm recurved to the northeast on the 11th and merged with an extra-tropical storm on the 14th. The combined storm was quite severe with one ship reporting 979 mb. (28.91 inches). The lowest reported pressure in the tropical storm was 1000 mb. (29.53 inches), and highest winds were about 55 m p. h.

*Katie, October 14–20.*—Hurricane Katie probably developed from a wave on the intertropical convergence zone in the vicinity of Panama. The first definite evidence was a ship report from the Dutch motor vessel *Poseidon* on the morning of the 16th. A Navy reconnaissance plane the same afternoon located the center with a pressure of 984 mb (29.06 inches) and winds up to 115 m. p. h. The center crossed the coastline of Hispaniola near the border between Haiti and the Dominican Republic about midnight that night. This area is thinly populated but the small border towns of Anse-a-Pitre and Pedernales were badly damaged with highest winds estimated at 115 m. p. h. On the basis of incomplete reports, total damage is estimated at between $200,000 and $300,000 with 7 deaths.

Katie became almost completely disorganized in crossing the high mountains of Hispaniola but briefly intensified to near hurricane intensity after passing out into the Atlantic. However, it shortly reached an area containing the remains of an old cold front and again lost intensity. The vortex was probably last encountered by the SS *Amsterdam* at 0130 EST on the 20th in Latitude 37.3° N. and Longitude 56.4° W.

## 3. ANALYSIS OF RADAR REPORTS IN CONNIE, DIANE, AND IONE

### RADAR OBSERVATIONS

A radar was installed at Hatteras, N. C., in July 1955, principally for the purpose of observing hurricanes as they passed northward either inland or out to sea on varying degrees of recurvature. A more fortunate and timely location could not have been selected since the three hurricanes which affected the United States coastline in 1955 passed within radar range of this station. Radar fixes and scope photographs for these hurricanes are to be published as a Weather Bureau *Technical Paper* to make them available for research and training purposes. In the meantime it seems appropriate to include in this annual review a brief analysis of the fixes for Connie and Diane. The fixes for Ione have already been analyzed by Jordan and Stowell [7].

All radar fixes between Latitudes 32° and 36° N. from the Hatteras station and the Navy and Air Force reconnaissance planes have been plotted for hurricanes Connie and Diane on figures 7 and 8. Hatteras radar fixes of the eye became reasonably accurate at a range of 140 nautical miles for Connie, 150 for Diane, and 160 for Ione.

Note the cyclonically curved movement of the apparent eye as indicated by aircraft radar from 0330 to 0500 EST and the two eye penetrations at 0550 and 0800 EST, and then the next eye position at 1020 EST to the south of the previous positions indicated by A at the bottom of figure 7. Compare the radar-indicated path during this period with the smoothed track of the hurricane. Was the plane following a parasitic circulation—a false eye? Note the anticyclonically curved cusps (B) from 2311 EST on the 11th to 0147 EST on the 12th and from 0147 to 0555 EST and perhaps another from 0555 to 0705 EST. Did the hurricane center actually take such a course and, if so, what is the explanation of the apparent anticyclonic curvature?

From 1100 EST on the 9th to 1700 EST on the 11th Connie moved at the rate of 5.7 m. p. h. After this time Connie began to accelerate but temporarily slowed as the center approached and crossed the North Carolina coastline. The center curved to the left just as it crossed the coast and made one or more loops, remaining quasi-stationary west and north of Morehead City for about 3 hours.

Hurricane Diane's path was the most straightforward of the three as the storm passed through eastern North Carolina. However, one loop was indicated by radar about 19 nautical miles off the coast and another possible small loop west of Wilmington (fig. 8). It will be noted that the eye remained in about the same position for 2½ hours off the coast and then was reported 31 minutes later some 33 miles to the northwest. The Hatteras observer provided us with a description of the events taking place as seen on the radar from 0317 to 0517 EST on this date—table 1. Some additional information was supplied by the Air Force plane which was in the eye at 0300 EST. It was dark, the plane was at 500 mb. and the observer reported:

Position 33.7° N., 77.4° W. [16 miles east-northeast of the interpolated Hatteras radar fix] loran position accurate within 5 miles, eye defined on radar, wall clouds on north semicircle, south semicircle open, eye well defined 45 miles in diameter, 500-mb. height 18,820 feet, alto-stratus and light rain in eye near north wall clouds, unable to make dropsonde due excessive static, lightning visible 60 miles south.

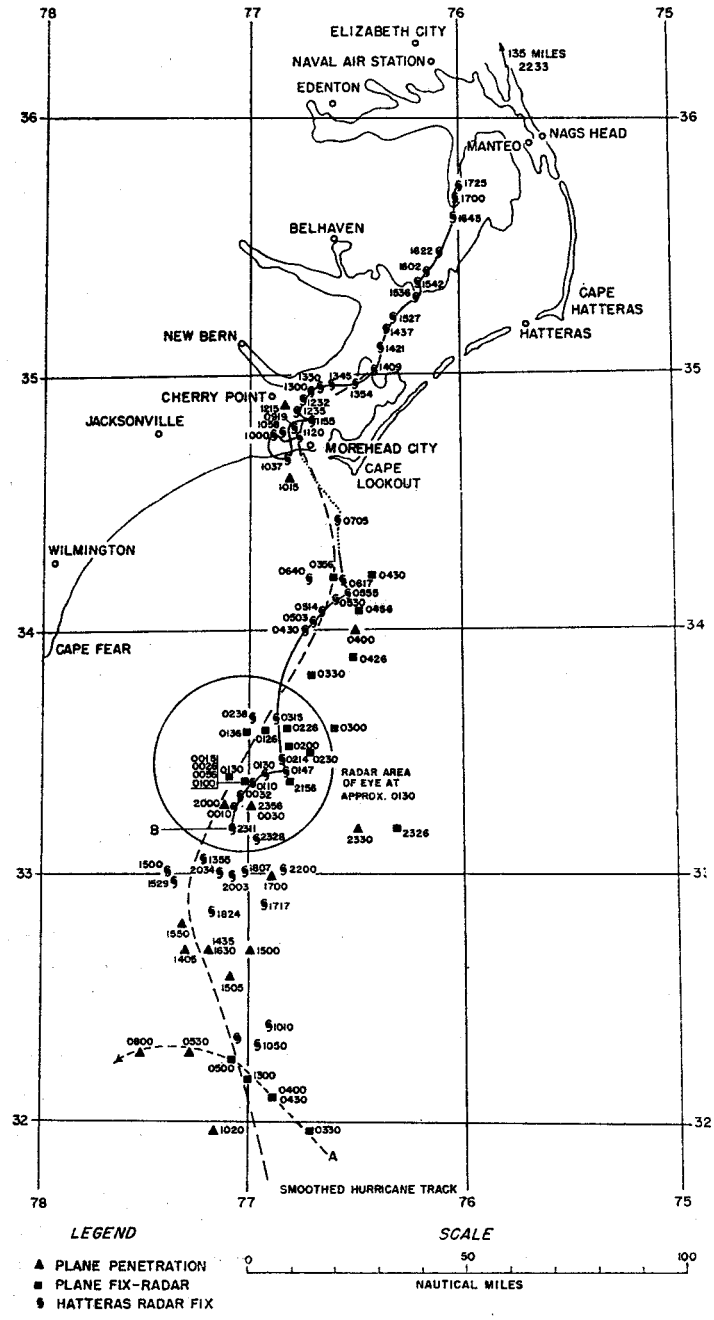


FIGURE 7.—Track and radar fixes, hurricane Connie, August 11–12, 1955.

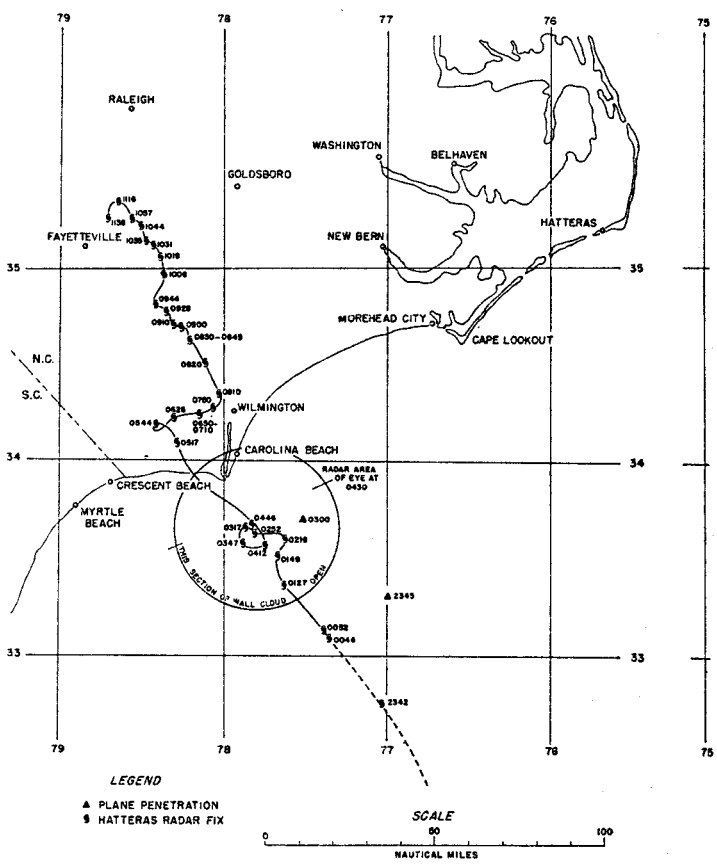


FIGURE 8.—Track and radar fixes, hurricane Diane, Aug. 16–17, 1955.

TABLE 1.—*Observer's description of events taking place in Diane as seen on the Cape Hatteras radar, 0317–0517* EST, *August 17, 1955*

| Time EST | Position of eye Deg./miles | Comments |
|---|---|---|
| 0317 | 229/140 | Eye still difficult to define. Spiral band bounding it on N side is 100 miles in diameter. |
| 0347 | 228/145 | Difficult to define. |
| 0412 | 226/140 | Difficult to define. |
| 0446 | 229/140 | Appears 50 miles diameter—difficult to define. |
| 0517 | 243/145 | Eye appears to form into tight curl at west side of huge spiral band. |

The combined plane and surface radar observations may be interpreted to mean there was a loosely defined squall eye 45 to 50 miles in diameter but the precipitation-free eye and possibly the wind eye were smaller. The squall eye did not move northwestward in straightforward fashion but the long intense spiral band moved into the old, large, and indefinite center and a new eye developed in the tight curl southwest of Wilmington. It seems definite the movement of the squall or radar eye, or whatever the radar was following, was discontinuous but it is not certain whether or not the precipitation and wind eyes moved regularly. In order to check this explanation and to see what the eye looked like from the ground, additional data were requested from Wilmington. Mr. R. L. Frost, the Meteorologist in Charge, replied as follows:

It is the opinion here that the "eye" arrived at 5 a. m. There was no marked change in the weather conditions. The sky remained overcast, the wind moderated but there was no period of calm. Evidently the hurricane was weakening and filling when it reached the coast here. It was hard to realize we were in the "eye", but from the barometric indications we must have been. The characteristic "hurricane eye weather" which we have read about in other hurricanes was missing in this storm. The lowest barometer reading was 29.13 inches at 8:15 a. m.

From the Form WBAN 10A for Wilmington, the peak gust occurred at 0249 EST. This was the intense weather

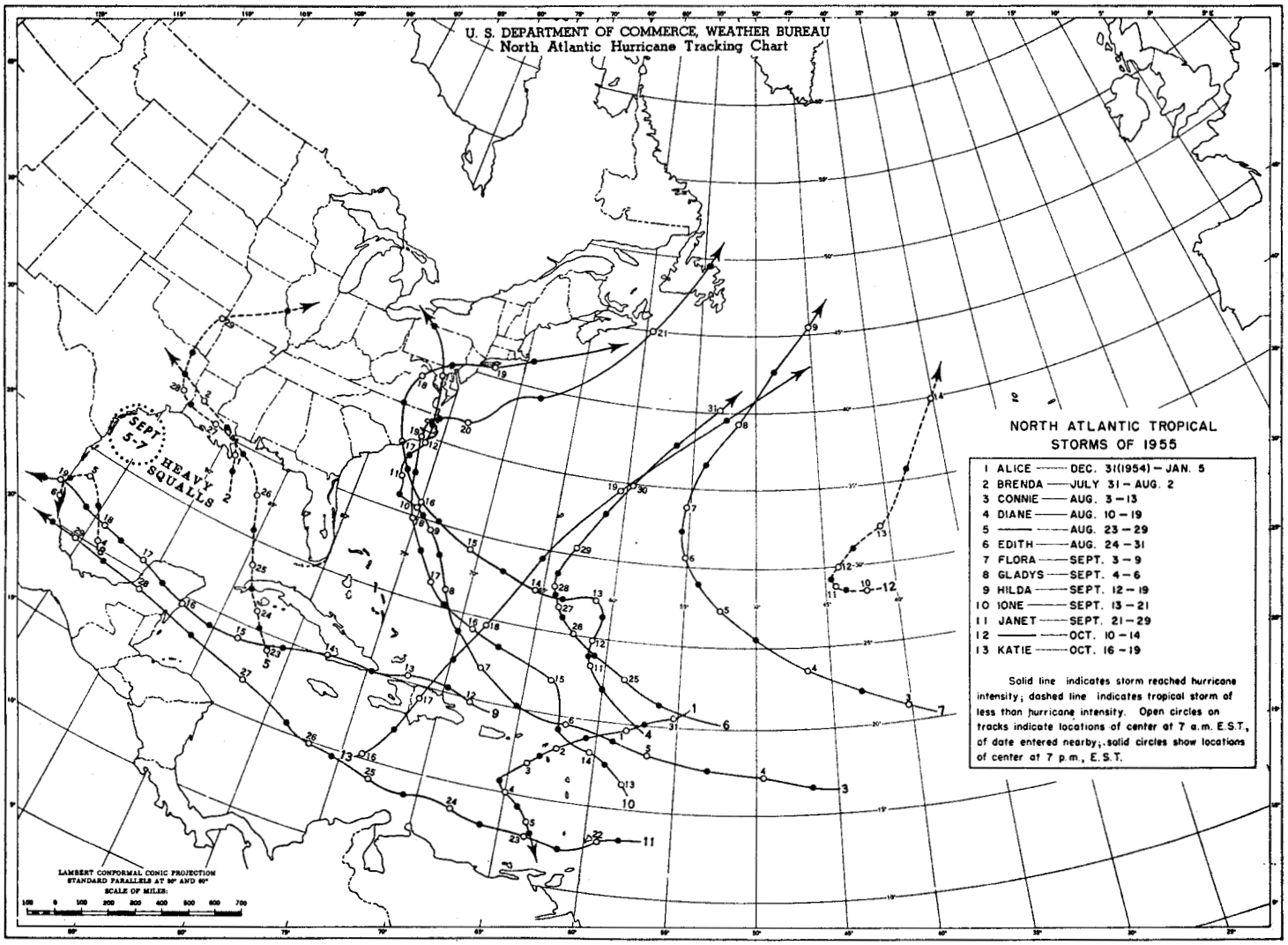


FIGURE 9.—Tracks of hurricanes and tropical storms, 1955.

band north of the eye noted on some of the radar reports. The winds and heavy rain gradually subsided until 0504 EST when "very light rain" was recorded with the remarks, "barometer steady, apparently in eye of hurricane, wind variable 10 to 25 m. p. h., breaks in overcast". The station was in the radar eye; however, intermittent light to occasionally heavy showers which were apparently not observed on the radar scopes continued until 0833 EST. At the time the radar eye was closest to Wilmington (7 miles), a heavy shower was occurring at the weather station. Highest wind after the eye passage was 45 m. p. h. with only 0.02 inches of precipitation. The wind and precipitation eye, although indefinite, would appear to have been much smaller than the radar or squall eye. By no means can the complex and disorganized eye description given by radar and ground observers at this stage of Diane be considered characteristic of hurricanes in general.

The rate of movement of Diane as the storm approached the coastline cannot be determined exactly because of the apparent discontinuous progression of the radar center but some deviation to the left and some slowing is evident while in the vicinity of and west of Wilmington. The tendency for disintegration of the eye was evidenced by the radar fixes as the center approached Raleigh, N. C. (1044–1138 EST).

The Hatteras radar observations taken in connection with Ione have been discussed by Jordan and Stowell [7]. From figures 1 and 2 in their article, the slowing and erratic movement and the turn to the left are clearly evident as Ione crossed the coastline. West of Morehead City the hurricane moved only 45 statute miles in 10 hours. There were apparently several loops and Cherry Point had 3 barometric minima, 28.42 inches at 0627, 28.43 at 0821 and 28.46 at 1030 EST. The magnitude of the rise in barometer between the minima is not known. This slow movement of Ione was probably the most important factor in the excessive rains in eastern North

Carolina, Maysville reporting 16.63 inches and New Bern 13.04.

In hurricane Connie some 24 Air Force and Navy radar and penetration fixes have been compared with the Hatteras radar fixes, interpolating for very short periods when necessary. The average deviation in center fixes was 10.5 nautical miles. Some 16 fixes were less than the median value and only 8 were greater. No comparisons were made in Diane since there were only two aircraft fixes. There were 15 comparable fixes in Ione and the average deviation was 9.7 nautical miles. In view of the large radar eye, occasionally as much as 50 to 60 miles in diameter, the agreement is considered excellent. The relative size of the radar eye has been indicated in figures 7 and 8.

## CONCLUSIONS

1. The turn to the left by all three hurricanes (Connie, Diane, and Ione) can be attributed to the frictional differential between that portion of the hurricane over land and the portion over water. Because of the increased frictional effect over land and the greater cross-isobaric flow there is an increase of mass and relative increase in pressure in the right front quadrant which deflects the center of lowest pressure to the left. As soon as the greater portion of the hurricane is over land, particularly the core of strongest winds not far from the center, and coincidental with some filling of the center and spreading of the isobars, the frictional differential decreases and the hurricane resumes its normal course. If the hurricane encounters a new source of energy in the form of cyclonic vorticity or of a strong thermal gradient, the deviation to the left is less pronounced due to increased asymmetry and to acceleration but usually some brief relative slowing still occurs. The greater retardation of forward progress in connection with Ione was due to the coincidence of the frictional differential with point of recurvature.

2. Radar is a powerful new tool in hurricane forecasting and research. However, additional radar research is urgently needed that the forecaster may know just what the observer sees on radar, the general relationships of radar, cloud, precipitation, and wind eyes or centers, and the physical processes which go on in each with time.

3. Hurricane radar reports require expert interpretation and no forecast should be based on one individual radar fix.

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