

PAPERS SUPPLEMENTING THE DISCUSSION OF THE WEST INDIAN HURRICANE OF SEPT. 6-14, 1919.

A TORNADO WITHIN A HURRICANE AREA.

By RICHARD W. GRAY, Meteorologist.

A tornado occurred at Goulds, Fla., a small town 20 miles southwest of Miami, on September 10, 1919, between 1:00 p. m. and 1:15 p. m., eastern summer time.

This tornado is of special interest in that it can be said to have occurred within a hurricane area. The severe tropical disturbance that passed through the Florida Straits and, several days later, caused such an appalling loss of life and destruction of property at Corpus Christi, Tex., was central during the afternoon of September 10 over the extreme southeastern Gulf of Mexico. The center of this storm, therefore, was probably within 125 miles of the path of the tornado, and the southern part of the Florida peninsula was still under its influence.

The high winds that prevailed over extreme southern Florida in connection with the tropical storm had diminished by the morning of the 10th, but a moderate gale was still blowing, and the wind continued at this force at Goulds until just before the occurrence of the tornado, when there was a lull for probably 15 minutes.

The tornado developed either over the ocean or Biscayne Bay, and its original form was undoubtedly that of a waterspout. It moved in a west-northwest direction, directly with the strong southeast wind that prevailed at the time on the southeast Florida coast. After leaving the bay, it crossed a 3-mile stretch of marsh land, and there were evidences that this part of the path was extremely narrow. It then entered a pine wood immediately east of Goulds, where the path rapidly widened. At Goulds, the path was about 600 feet in width. After passing over Goulds, the storm moved over a cleared area of about one-half mile in extent, when it entered another pine wood. It is interesting to note that the path through this second wood was 100 feet, or less, in width. The storm continued west-northwest, and was seen to disappear over the Everglades, about 14 miles from the point of entry on the shore of Biscayne Bay. Fig. 1 shows the tornado path.

The tornado was attended by the characteristic pendant cloud, which was described by several persons as having a waving motion, with the detached end apparently moving through a space of 100 feet. It was not accompanied by rain, but the air in the path of the storm was filled with a fine mist.

There were many evidences of the whirling motion of the air. In the first wood through which the storm passed (fig. 2), the uprooted and broken trees apparently fell in all directions. At Goulds, débris from a demolished building was carried across the path of the storm and deposited on the side opposite to which the building stood. A hotel and a large packing house, which were on the northern edge of the path, were lifted from their foundations and moved 15 feet toward the center of the path.

In the second wood (fig. 4), where the path had narrowed to 100 feet, or less, there was no indication of a whirl. All the fallen trees, with one exception, lay with their tops toward the northwest, being practically parallel. One tree which fell toward the southwest was apparently leaning in that direction before the storm occurred. The fallen trees in this narrow part of the path indicated a straight blow, and it was apparently here that the storm developed its greatest force. A dwelling in a small clearing in this wood was completely demolished, and the concrete foundations of the house were pulled out of the ground. Many of the trees had

large pieces of tin and sheet-iron roofing wrapped around them, or lodged in their tops (figs. 4 and 5), these pieces of roofing being part of the débris from wrecked buildings at Goulds, about 1 mile to the east.

At Goulds, 19 buildings were damaged and 6 were demolished. Some of the damaged buildings will have to be practically rebuilt. The monetary loss was approximately \$25,000.

There was no loss of life in connection with the storm, but five persons were injured by flying débris, and one girl was seriously cut by a piece of flying glass. The absence of fatal accidents was due to the fact that the occupants of all buildings that were demolished heard the approaching storm in time to escape into the open, where they threw themselves upon the ground.

In one instance, five persons escaped injury by taking refuge behind a large boiler. This boiler was struck by pieces of flying timber from the building that had just been vacated.

In another case, a man ran out of the rear of a building just as it was on the point of collapsing. The roof of the building passed over his head, and he was uninjured.

Mr. W. H. Cawley saw the storm approaching, and, getting into his automobile, he started for his home, which is a short distance west of Goulds. He was overtaken by the storm and by flying débris, and a large piece of sheet iron struck the top of the automobile and cut it off, without otherwise damaging the car. Upon arriving home, Mr. Cawley found that his residence was intact, but that his garage, which was within 50 feet of the house, had been demolished.

The post office was one of the buildings completely destroyed, and the postmaster escaped from the building only a few seconds before it was razed. Fortunately, he ran to the rear of a packing house, which, though lifted from its foundations, was not blown down. He was thus protected from flying débris, with which, he states, the air seemed to be filled.

SPECIAL FORECASTS AND WARNINGS. WEATHER AND CROPS.

WEATHER WARNINGS, SEPTEMBER, 1919.

By H. C. FRANKENFIELD,

Supervising Forecaster.

[Dated: Weather Bureau, Washington, Oct. 22, 1919.]

Except for the West Indian hurricane described in detail below, there were no storms of consequence during the month, and the few warnings that were ordered on the Great Lakes and along the Atlantic coast failed for the most part of verification.

FROST WARNINGS.

On the morning of the 4th, with high pressure over Minnesota and the upper Lake region, possible light frosts were forecast for the following morning over upper Michigan, but the forecast was verified over the eastern portion only, low pressure approaching rapidly from the Northwest. On the morning of the 13th high pressure and comparatively low temperature prevailed over the Lake region and the Ohio Valley, with low pressure to the eastward, and local frosts were forecast for the following morning in New England and the Middle Atlantic States. However, the rise in pressure ceased and there were no frosts. The frosts on the morning of the 18th over northeastern New York and New England were forecast.

On the morning of the 25th there was a well-marked disturbance over central Ontario, with rapidly rising pressure to the westward, and frosts were forecast for Michigan on the following morning. These warnings were verified, the frost having been heavy in some localities. Frost was then forecast for the morning of the 27th for New England, New York, and the extreme northern portions of New Jersey and eastern Pennsylvania, and these forecasts were also verified.

AVIATION FORECASTS.

Special aviation forecasts were made for the Army and Navy balloon race on the 26th and for the National balloon race on October 1, both from St. Louis, Mo., and also for the early days of the recruiting tour of the United States Navy hydroplane, *NC 4*.

THE WEST INDIAN HURRICANE OF SEPTEMBER 6-14, 1919.

BEGINNINGS OF THE CYCLONE.

So far as observational data are concerned, the exact genesis of the tropical storm of September 6-14 is somewhat shrouded in doubt. Although not in strict accordance with the normal behavior of previous storms, it appears to be a reasonable assumption that this storm owed its inception to a redevelopment of the minor disturbance that was first noted on the evening of September 2 in the vicinity of latitude 17° or 18° north and longitude 63° west, or a little west of the island of Antigua. This first, or minor, disturbance, moved west-northwestward at about a normal rate, passing near the southern portion of the island of Porto Rico, and by the evening of the 4th it had reached the north coast of the island of Santo Domingo with a barometer reading of about 29.80 inches. On the morning of the 5th the center of the disturbance was approximately 100 miles southwest of

Turks Island with about the same barometric pressure, and with an east wind at Turks Island, and light southwest winds at Puerto Plata. By the evening of the 5th the winds at Turks Island had changed from east to west, and were southerly over Santo Domingo and Haiti, still light in character, apparent evidence that the disturbance had recurved to the northeastward during the day, and that it was moving in that direction in very moderate form. At this writing no details regarding this storm have been received. Special observations taken at 2 p. m., September 3 at St. Thomas, Virgin Islands, and San Juan, P. R., showed a maximum wind velocity of 48 miles an hour from the southeast at the former, and of 32 miles an hour from the east at the latter place, but no other strong winds were reported until the morning of the 6th, when Turks Island reported a maximum wind velocity of 30 miles an hour from the south during the night.

THE HURRICANE IN SOUTH FLORIDA.

On the evening of the 6th pressure and wind conditions over Santo Domingo and the Bahamas indicated the possible presence of a disturbance over the eastern Bahamas. Conditions were slightly more pronounced on the morning of the 7th, and special observations were called for from Nassau and from Miami, Fla., the message stating that there were slight indications of a disturbance over the central Bahamas. However, no afternoon report was received from Nassau, and the evening report was not received until 9 a. m. of the 8th, about 12 hours late. By this time the wind at Miami was blowing 26 miles an hour from the northeast, with slowly falling pressure, and it became apparent that the storm was one of considerable intensity. Accordingly at 10 a. m. northeast storm warnings were ordered on the Florida coast from Jupiter to Key West, and thence northward on the west coast to Fort Myers. At the same time the usual advices were sent to all interests along the Atlantic and Gulf coasts, and special observations were ordered taken at frequent intervals during the day. Hurricane warnings were ordered displayed at 1 p. m. from Jupiter to Key West, the order reading as follows:

Change to hurricane warnings 1 p. m. Jupiter to Key West. Delayed report from Nassau, barometer 29.46 and wind 56 miles from northeast. Storm center will probably reach south Florida coast by to-night, attended by dangerous northeast winds. Caution all vessels to avoid the Florida Straits and the east Florida coast until further notice.

At 2 p. m. northeast storm warnings were ordered at Tampa, Fla., for strong winds in that vicinity, and all shipping cautioned to delay until the storm had passed.

Emergency warnings for dangerous winds were also given the widest possible distribution throughout southern Florida.

At 1 p. m. of the 9th hurricane warnings were continued at Key West and changed to northeast storm warnings from Jupiter to Miami. The northeast warnings were also continued on the west Florida coast north of Key West to Tampa. At 9 p. m. of the 9th the following special warning was issued:

Tropical disturbance 4 p. m. apparently over Florida Straits, a short distance south of Key West with greatly increased intensity, and probably moving northwest. It will enter the Gulf of Mexico Tuesday night and continue its northwestward movement. All Gulf shipping north of latitude 25° warned to avoid the probable path of the storm.

The storm center passed about 30 or 40 miles south of Key West about midnight of September 9. At this time the barometer at Key West read 28.83 inches with an east wind of an estimated velocity of 105 miles an hour, which increased slightly during the next hour. At Sand Key the lowest barometer at about the same time was 28.35 inches, a difference of 0.48 inch within a distance of 8 miles.

THE STORM AT KEY WEST AND VICINITY.

The following report on the storm at Key West and vicinity was prepared by Mr. H. B. Boyer, official in charge of the Weather Bureau office at that place:

"The storm that passed over Key West on September 9 and 10 was, without question, the most violent experienced since records at this station began. While the minimum barometric reading, 28.81 inches, was not as low as that recorded in 1909 (28.52) and in 1910 (28.47), the violence of the wind was undoubtedly greater. It is to be regretted that owing to the vibrations of the tower supporting the wind instruments the anemometer cups were shaken loose and blown away at 7:30 p. m. on the 9th in gusts ranging between 75 and 80 miles an hour, and thereafter until 3:35 p. m. of the 10th the wind-velocity record was lost. The wind-vane was blown away at 12:45 a. m. of the 10th during the winds of greatest intensity, and at 3:16 a. m. the collector of the recording rain-gage was blown off and the door forced open. The thermometer shelter held and temperature data are unbroken. In estimating the lost data great care has been taken, advantage having been taken of notes made throughout the storm, and further advantage taken of the fact that the official in charge has experienced five hurricanes, which enables him to make a fairly accurate comparison.

"The first warning was received on the 8th at 9:55 a. m.:

"Hoist northeast storm warning 10 a. m. Jupiter to Key West and at Fort Myers, Fla. Disturbance near or over southwestern Bahamas apparently moving west-northwest. Strong northeast winds Monday, and will probably increase to gale force. Advise great caution until further advices later in the day.

"Storm warnings were immediately displayed, and the information disseminated.

"At 1.05 p. m. the following was received:

"Change to hurricane warnings 1 p. m. Jupiter to Key West. Delayed report from Nassau: Barometer 29.46 and wind 56 miles from the northeast. Storm center will probably reach south Florida coast to-night attended by dangerous northeast winds. Caution all vessels to avoid the Florida Straits and the east Florida coast until further advices.

"Hurricane warnings were immediately displayed and the information disseminated by every available means. The response to this warning was immediate and there followed a period of great activity, especially as regards shipping. Vessels were moved to safer anchorage or better secured, and all weak places in residences and buildings of all descriptions were strengthened as much as possible by nailing and battening doors, windows, roof hatches, etc. In the terrific gusts that prevailed during the height of the storm stanch brick structures had walls blown out and large vessels, firmly secured, were torn from their fastenings or moorings and blown on the banks. Notwithstanding the great loss, estimated

at \$2,000,000, the official in charge has been the recipient of many congratulations on the splendid service rendered by the Bureau.

"Owing to the very slow progressive movement of the storm in this vicinity, winds of gale force and over lasted continuously from about 7 a. m. of the 9th to about 9:30 p. m. of the 10th. The apex of the hurricane was reached on the 9th at midnight when the center, moving slowly west-northwest, was south of and nearest the station. The center when at its nearest point was probably about 30 or 40 miles distant.

"Following is an hourly tabulation covering the period during which winds of gale force prevailed:

	Barometer.	Wind direction.	Maximum velocity.	Weather.
SEPT. 9.				
	<i>Inches.</i>		<i>Miles per hour.</i>	
7 a. m.....	29.61	ne.	36	Light rain.
8 a. m.....	29.61	nne.	38	Do.
9 a. m.....	29.58	n.	36	Threatening.
10 a. m.....	29.56	nne.	39	Light rain.
11 a. m.....	29.54	ne.	40	Do.
12 noon.....	29.50	ne.	37	Do.
1 p. m.....	29.46	ne.	42	Do.
2 p. m.....	29.40	ne.	44	Moderately heavy rain.
3 p. m.....	29.31	ne.	48	Do.
4 p. m.....	29.27	ne.	50	Do.
5 p. m.....	29.22	ne.	54	Do.
6 p. m.....	29.13	ne.	58	Do.
7 p. m.....	29.08	ne.	58	Heavy rain.
8 p. m.....	29.05	ne.	70	Do.
9 p. m.....	28.99	ne.	1 80	Do.
10 p. m.....	28.97	ne.	1 85	Do.
11 p. m.....	28.93	ne.	1 90	Do.
12 midnight.....	28.81	e.	1 105	Do.
SEPT. 10.				
1 a. m.....	28.90	e.	1 110	Do.
2 a. m.....	28.96	e.	1 100	Do.
3 a. m.....	29.02	e.	1 90	Do.
4 a. m.....	29.07	e.	1 85	Do.
5 a. m.....	29.13	se.	1 80	Do.
6 a. m.....	29.20	se.	1 70	Do.
7 a. m.....	29.26	se.	1 70	Do.
8 a. m.....	29.35	se.	1 70	Do.
9 a. m.....	29.39	se.	1 60	Light rain.
10 a. m.....	29.44	se.	1 55	Do.
11 a. m.....	29.46	se.	1 50	Do.
12 noon.....	29.50	se.	1 48	Do.
1 p. m.....	29.53	se.	1 48	Do.
2 p. m.....	29.52	s.	1 45	Do.
3 p. m.....	29.56	s.	1 40	Do.
4 p. m.....	29.57	s.	1 40	Do.

¹ Estimated.

"From the forenoon of the 9th squalls of wind and rain progressively increased in force and frequency, culminating in terrific gusts of great violence between midnight of the 9th and 2 a. m. of the 10th. As the storm's center slowly passed into the Gulf of Mexico to the westward the squalls and gusts gradually became less violent and of less frequency.

"The usual phenomena preceding, accompanying, and following storms of tropical origin were present in this one; and while no thunder was heard, diffused lightning was noted at intervals for several hours before the maximum force was reached.

"As previously stated, the property loss is estimated at \$2,000,000, the air station alone losing about \$800,000. Probably not a structure on the island escaped being damaged more or less, the Weather Bureau building and grounds suffering quite badly. Three lives were lost by drowning.

"The rainfall was extremely heavy and continuous. The loss of rainfall record is unfortunate, but from the partial record obtained and from notes made the total amount is estimated at 13.39 inches, the heaviest occurring during the early morning hours of the 10th.

"The demands made on the office force were beyond their ability to perform, but every effort was made to meet all emergencies. What with the duties of the station, answering the constantly ringing telephone, giving advice and information to callers, and throughout the night of the 9th-10th working to make the building more secure, the strain came near the breaking point. The official in charge had no sleep from the morning of the 8th until the night of the 10th, and this is also true of Assistant Observer J. C. McCarthy, whom I commend without reserve for giving unstinted support throughout the period of stress.

Through the courtesy of Admiral Benton C. Decker, commandant seventh naval district, who placed the motor sailer of the gunboat *Wheeling* at my disposal, I proceeded to Sand Key on the 12th to look after the welfare of the employees at that station and to inspect the station. As the island was completely washed away and seas breaking over, a landing was impossible. Repairman Saunders swam out and piloted us in to a point near the lighthouse, where the sea was comparatively quiet. The personnel were found safe. As previously instructed, they had abandoned the Weather Bureau building and gone to the lighthouse for greater safety. The 85-foot tower had buckled about 20 feet above the foundation pillars and fallen across the south side of the building, which was intact and but little damaged. The four cisterns are gone, and also the steps; most of the brace rods are badly bent. The motor boat was swept away and lost. I am informed by Repairman Saunders that as the interior of the Weather Bureau was found in so much better condition than the lighthouse quarters the men returned to it by wading and swimming and immediately entered upon the duties of vessels reporting. All instruments exposed in the open were blown or washed off."

The report of the storm experiences at Sand Key, Fla., was prepared by Mr. Eugene M. Barto, observer, and is as follows:

The first warning of the hurricane was received Monday noon, when the northeast storm warnings were changed to hurricane warnings. Instructions were received to take no chances whatever, so preparations were begun in case it became necessary to move to the lighthouse.

The barometer fell steadily and the wind increased during the night (p. m.) of the 8th and night (a. m.) of the 9th. After a squall which ended at 4:30 a. m. we began moving the extra instruments, records, flags, telescope, typewriter, bedding, etc. This continued until 1 p. m., when the station was closed and abandoned. The noon observation of the 9th was the last one taken. The velocity of the wind was 65 miles an hour and rain was falling, thus making it impossible to see more than 100 yards away.

The hurricane warning flags were blown down at 3:30 p. m. The rain gage was washed away about 6:30 p. m. by the waves, which completely covered the island. The motor boat which had been doubly secured to her moorings broke away at 7 p. m. The instrument shelter was badly damaged and wedged in the tower of the building at 7:30 p. m. At 8 p. m. the waves washed away the shed under the Weather Bureau, together with the ice chest and five cans of carbide. Shortly after this the four water-tanks were broken up and washed away. Two of the cement platforms upon which the tanks rested were washed off their pillars while a third was damaged by the waves.

The storm warning tower was blown down shortly after 10 p. m., breaking off at a height even with the roof of the building, thus extinguishing the hurricane warning lights. The tower fell on the south side of the building, broke all three lights, tore up the roofing, and tore away one-half the cornice. One of the four sides of the cement support of the storm warning tower which rests upon pillars was forced and badly cracked, part of which has already fallen down.

The iron steps of the building were broken away and washed about 30 feet. Two iron collars around a pillar of the building were broken by something washing against one of the braces.

The record showed that the anemometer cups blew away at 9:35 p. m. with a wind velocity of 84 miles an hour. The wind vane was

probably blown away shortly after midnight. This was also the time of the lowest barograph record, which was 28.35.

A window casing of the lighthouse was blown in, thus exposing the typewriter to the salt water which rendered it useless.

The storm continued during Wednesday and Thursday, the wind and rain making it impossible to see vessels. Watches were resumed Thursday morning, September 11, at daybreak and signal work was carried on from the lighthouse until 10 a. m. Friday morning, when it was again resumed at the Weather Bureau.

Friday and Saturday were spent in transferring articles from the lighthouse to the Weather Bureau by means of rope stretched from one building to the other. This method was necessary because the water was several feet deep on the island.

The instruments were taken care of, wires tested, and the building cleaned and put in order. The extra anemometer was put up at midnight Sunday and the extra sunshine recorder Monday morning. Observations were resumed at 8 a. m. Monday, September 15, 1919. The instrument shelter was put in serviceable condition on the 16th and the thermometers were exposed at midnight.

Details of barometer, wind, and rain observations follow:

The barometer reading at 8 p. m. of the 8th was 29.77, reduced, and the wind velocity was 36 miles an hour from the north. The barometer fell steadily during the night, while the wind, which continued in the north, increased. The barometer reading at 8 a. m. of the 9th was 29.59, and the wind velocity 50 miles an hour from the north. The barograph showed a steady fall until 12.10 a. m. of the 10th, when it reached its lowest point, 28.35. It rose steadily throughout the 10th, showing a record of 29.66 at midnight. The prevailing wind direction was north until 12 noon of the 9th, when it shifted to the northeast. It continued in this direction until 10.10 p. m., when it changed to south. It later shifted to the southeast at 10.46 p. m., and at 12.17 a. m. of the 10th shifted to the east, at which time the wind vane probably blew away. The wind increased rapidly, reaching a maximum velocity of 65 miles an hour from the northeast at 12.48 p. m. of the 9th, after which higher velocities were registered at intervals until the highest was recorded, which was 94 miles an hour from the northeast at 8.39 p. m. The hourly wind movement from 2 to 3 p. m. was 77 miles; from 3 to 4 p. m., 76 miles; from 4 to 5 p. m., 59 miles; from 5 to 6, 57 miles; from 6 to 7 p. m., 64 miles; from 7 to 8, 77 miles; from 8 to 9 p. m., 84 miles, and from 9 to 9.35 p. m., 50 miles, at which time the instrument blew away.

A trace of precipitation fell on the 8th between 11.20 and 11.35 p. m. During a squall between 3.15 and 4.35 a. m. of the 9th, 0.36 inch fell. Rain again began to fall at 9.25 a. m. and continued until the night of the 10th. The amount could not be determined because the rain gage was washed away by the waves.

Below is given a portion of the log of the steamship *Winona*. It will be remembered that the *Winona* went ashore near the Pulaski Shoals at the northeast portion of the Dry Tortugas group, her master having been unable to determine his position on account of the storm.

Log of steamship Lake Winona (Capt. Roper), from New Orleans, La., to San Juan, P. R.

SEPTEMBER 9, 1919.

- 4:00 a. m. Fresh breeze and a moderate sea. Cloudy, with passing rain squalls.
 6:00 a. m. Strong breeze, increasing fast.
 7:10 a. m. Half speed; hove to on port bow; half gale blowing, with heavy rain squalls; high seas running; heading ENE., making little headway.
 1:00 p. m. Boatswain broke left leg catching same in starboard galley door with intention of closing it.
 3:00 p. m. Blowing a gale of wind. Part of bunker coal on forward deck washed overboard. Going slow astern. Hurricane blowing. Second mate had leg cut seriously. Wind changeable from northeast to northwest, blowing a hurricane; 90 miles an hour; riotous sea running, and half speed ahead; ship behaving well in sea, but not steering. Squally and terrific wind blowing from northwest; drifting to the eastward; ship not steering.

SEPTEMBER 10, 1919.

- 1:00 a. m. Heavy sea running, with terrific squalls of long duration; ship not steering; force of wind about 125 miles an hour; drifting to the northward and eastward.

6:00 a. m. Heavy sea running with terrific wind of hurricane force; making northeasterly course; ship not steering. At 10 a. m. ship struck reef, but not knowing what position or reef could be on account of having no observation since 8th. Got port boat ready in case of necessity, swung out and lashed to rail. Two men went in to bail out same. Wind veered around to northwest; heavy sea returned, hitting bow of lifeboat, which broke forward ring. Another sea struck lifeboat, lifting her out of water, parting painter; men climbed to stern of lifeboat and in doing so tripped stern hook, leaving boat free to drift away; tried to throw them lines, but boat drifted too fast. A. B. sailor named Edward Purretto and Andrus Pulvels, O. S., were in the lifeboat and were lost with it; 12 noon. During this time of ship's striking reef the pipe connections between port and starboard boilers broke, rendering useless. Ship pounding heavily, with seas breaking over her. Let go starboard anchor and opened tank valves to fill same and keep ship steady. Port anchor not working through windlass being strained by pounding of heavy seas. Toward sundown wind moderated, with rising barometer.

Steamer Lake Winona.

	Wind direction.	Pressure.		Wind direction.	Pressure.
SEPTEMBER 9.			SEPTEMBER 10—CON.		
4 a. m.	ne.	29.78	9 p. m.		27.80
6 a. m.		29.70	10 p. m.	se.	
7 a. m.	ne.	29.68	12 midnight	se.	
8 a. m.	ne.	29.64	SEPTEMBER 11.		
9 a. m.	ne.		3 a. m.	se.	27.90
10 a. m.		29.50	7 a. m.	se.	
12 m.	n.	29.40	10 a. m.	se.	27.96
4 p. m.	n.	27.70	3 p. m.	se.	28.40
8 p. m.	n.	27.55	7 p. m.	se.	
12 midnight		27.45	11 p. m.	se.	28.45
SEPTEMBER 10.			SEPTEMBER 12.		
1 a. m.	nw.	27.60	2 a. m.		29.20
4 a. m.	nw.	27.55	6 a. m.	se.	
8 a. m.	se.	27.50	8 a. m.		29.40
10 a. m.	se.	27.55	1 p. m.		29.60
11 a. m.	nw.		6 p. m.	se.	29.86
2 p. m.	nw.	27.80			
4 p. m.	nw.				
6 p. m.	se.				

IN THE GULF.

With one or two unimportant exceptions no reports were received from the Gulf of Mexico after the morning of the 10th until after the storm had passed into Texas, which was during the day of the 14th. It was therefore absolutely impossible to forecast the intensity and progress of the storm, and the coast stations, far from the center of the storm, afforded but meager information.

During the afternoon of Wednesday, September 10, the northeast warnings at Tampa were ordered continued for another day for strong winds off the coast, and at 10:30 p. m. northeast warnings were ordered along the Gulf coast from Carrabelle, Fla., to New Orleans, La., the message reading as follows:

Hoist northeast storm warning 10:30 p. m. Tropical storm probably about latitude 26°, longitude 85°, moving northwest. Dangerous winds Thursday over southeast Gulf, and increasing northeast winds over central and northeast Gulf, probably becoming strong on coast by Thursday night. While exact location and movement of storm can not now be determined, every precaution should be taken against dangerous winds on the coast within 36 hours.

After this time the exact path of the storm center was conjectural, and at 4 p. m., September 11, the following warning was issued:

Hoist hurricane warning 4 p. m. Louisiana coast to Carrabelle. Tropical storm in north-central Gulf of Mexico, still moving northwest, probably near latitude 27 and longitude 87. Will likely reach middle Gulf coast to-night, and warnings of Wednesday night to take every precaution against dangerous winds repeated.

Vessel reports received by mail some time afterwards indicated that the position given above was a little too far north of the storm center, perhaps as much as 1°. At the same time emergency warnings were issued for inland points in extreme northwestern Florida and the southern portions of Alabama, Mississippi, and Louisiana.

At 9 p. m., September 11, northwest storm warnings were ordered along the Texas coast from Port Arthur to Velasco.

In the absence of definite information and in the hope that even a single radio report might be received from the Gulf, no further advices were issued until after the receipt of special observations in the early afternoon of September 12, when the following telegrams were given widespread distribution:

Observer, New Orleans, La.:

Continue hurricane warning Louisiana coast. No further definite information regarding storm. Now probably near latitude 27° 30' and longitude 89°. Further advices to-night; also earlier if any definite information received. Warnings changed to storm northeast Mobile and Pensacola, and hurricane warnings continued Mississippi coast.

Displayman, Bay St. Louis, Pass Christian, Gulfport and Pascagoula, Miss., and Observer, Mobile, Ala., and Pensacola, Fla.:

Continue hurricane warning 4 p. m., Bay St. Louis to Pascagoula, and change to storm northeast warning Mobile and Pensacola. No radio reports to-day. Storm center probably now near latitude 27° 30' and longitude 89°. Further advices to-night; also earlier should any definite information be received.

At 5:53 p. m. the following was also widely disseminated:

Four p. m. reports indicate probability of storm reaching east Louisiana coast to-night.

Later reports indicated that this probability did not become a fact. However, the statement had not been put forth as conclusive, and at 7:30 p. m. special 10 p. m. observations were called for and instructions issued to request the Gulf coast telegraph offices to remain open until later advices could be received. These were sent at 11:30 p. m., as follows:

Regret that no radio reports were received from Gulf of Mexico during the entire day. Increasing northeast winds at mouth of Mississippi River indicate that storm is not far to southward of that locality, and we can only repeat previous messages urging great caution until further advices Saturday morning. Good night.

The morning observations of September 13 at coast stations did not present any reasons for a change in the advices of the previous night, and information to that effect was issued. The barometer at the mouth of the Mississippi River had fallen 29.60 inches, and a 40-mile southeast wind was blowing, increasing to 53 miles an hour about 7:30 p. m.

The 8 p. m. observations of the 13th were the first to afford any indication that the Louisiana coast would likely escape the full violence of the storm, and after the receipt of 10 p. m. special observations the following warning was put forth at 11:30 p. m.:

Disturbance apparently central in Gulf south of Galveston. Barometer on coast steady, with slight rising tendency last two hours and is low over entire west Gulf. As center of disturbance can not be located, watch barometer carefully during night, and take all possible precautions against rising winds and higher tides, especially if barometer begins to fall steadily.

Some hours previously northwest storm warnings had been extended to cover the entire coast of Texas.

On the morning of September 14 the storm center was not far from the coast of Texas, between Corpus Christi and Brownsville, and during the day it passed inland, with marked although with steadily diminishing intensity.

REPORT FROM NEW ORLEANS.

Advisory messages relative to the tropical disturbance, warning all shipping to avoid the probable path of the storm, began to be received at New Orleans on the 8th, when the disturbance was over the western Bahamas, and these warnings were distributed to West Gulf shipping points and display stations.

On the 10th at 9:30 a. m. we advised all vessels at Louisiana coast points to remain in port, and small-craft warnings were displayed to prevent fishing vessels from venturing far from shore.

On Wednesday, September 10, at 10:40 p. m. northeast storm warnings were displayed at New Orleans and elsewhere in extreme southeastern Louisiana, increasing northerly winds being predicted for Thursday. This warning was extended westward to Morgan City on the 11th at 9 a. m.

Hurricane warnings for the Louisiana coast were ordered by the Washington office at 4 p. m. on the 11th, and shortly afterwards emergency warnings "to notify all interests to take every precaution against dangerous winds to-night and Friday" were received from Washington. These warnings were given the widest possible distribution. In addition to the warnings sent to the usual lists at Government expense they were carried by boats to Barataria Bay and Grand Isle. A boat was hired at Lake Charles, and the warning was disseminated by this means to the isolated sections of Cameron Parish in the extreme southwestern portion of the State. The telegraph and telephone companies and the Louisville & Nashville Railroad Co. kindly cooperated in the distribution. The city government and the press at New Orleans and elsewhere also gave wide distribution to the warnings.

The following warnings were issued from New Orleans:

SEPTEMBER 11, 1919.

Hoist northwest storm warning 9 p. m. Port Arthur to Velasco, Tex. Tropical disturbance now over north-central Gulf will probably cause increasing northerly winds on east coast of Texas Friday and caution advised.

SEPTEMBER 12, 1919.

Hoist northwest storm warnings 9 a. m. Texas coast west of Velasco to Corpus Christi. Change to northeast warnings Port Arthur to Velasco. Tropical disturbance in Gulf will cause increasing northerly winds next 24 hours, probably reaching gale force. Precautions should be continued.

The hurricane warnings on the Louisiana coast were continued at 4 p. m. on the 12th on orders from Washington, and this warning also was thoroughly distributed. Later we were advised from Washington that the 4 p. m. reports indicated the probability of the storm reaching the Louisiana coast that night, and another message, received at 11:05 p. m., stated that increasing winds at the mouth of the Mississippi River indicated that the storm was not far southward of that locality.

The wind at Burrwood, La., at the extremity of Southwest Pass, an outlet of the Mississippi, increased considerably on the night of the 12th-13th; at 7 a. m., a velocity of 40 miles an hour from the southeast was reported, and the barometer at 29.60 was 0.10 lower than 12 hours before. A moderate but increasing wind from the east prevailed at New Orleans at this time with intermittent rain gusts of higher velocity.

The following was received from Washington September 13, at 11:15 a. m.:

Advisory: Tropical storm now close to east Louisiana coast, apparently maintaining northwest movement, but with evidences of recurring. Will cause dangerous easterly gales eastern Louisiana and southern Mississippi and strong easterly winds southern Alabama and extreme northwest Florida, beginning this afternoon. Winds will shift to southeast and south by Sunday morning.

These warnings were distributed fully, and conditions up to 2 p. m. of the 13th tended to confirm them, for the tide continued to fall slowly at Galveston, Tex., but increased to a marked degree along the Louisiana coast. The tide was 6 feet above normal on Lake Borgne and on Grand Isle, and 5 to 6 feet above normal on Lake Pontchartrain, on the afternoon of the 13th. The Louisville & Nashville train schedule was annulled on account of water over the track near Lake Borgne. The tide overflowed the resorts at Spanish Fort and Bucktown, on Lake Pontchartrain, to a depth of a few feet and caused damage to the extent of a few thousand dollars. At Grand Isle the salt water covered the cultivated land to a depth of 1 foot and ruined the cauliflower crop, valued at \$30,000. Fresh to strong gales continued at Burrwood throughout the 13th, the highest velocity being 53 miles an hour, at 7:26-7:31 p. m. Strong winds prevailed at New Orleans, mostly from the east, but for short periods from the southeast.

Storm warnings on the Texas coast were changed from northeast to northwest, as follows:

SEPTEMBER 13, 1919.

Change to northwest storm warning 9 a. m., Port Arthur to Velasco, Tex. Tropical disturbance moving into Louisiana west of mouth of Mississippi River will cause strong northerly to westerly winds on east coast of Texas, with moderate to fresh northerly gales on extreme east coast.

During the afternoon of the 13th, special observations showed slowly falling barometer on the Texas coast, with some increase in the tide and the southeast swells at Galveston, and the following warning was issued:

Hoist northwest storm warning 6:30 p. m., Texas coast west of Velasco to Brownsville. Tropical disturbance in Gulf will cause increasing easterly to northerly winds, probably gales, on Texas coast Saturday night. Change to northeast storm warning Port Arthur to Velasco. Further advices later. Rising tide.

The following message was sent at 11:30 p. m. on the 13th direct from Washington to Port Arthur, Galveston, and Corpus Christi:

Disturbance apparently central in Gulf south of Galveston. Barometer on coast steady, with slight rising tendency last two hours and is low over entire west Gulf. As center of disturbance can not be located, watch barometer carefully during night and take all possible precautions against rising winds and higher tides, especially if barometer begins to fall steadily.

We were advised by the Galveston office next morning that warning to take protective measures was spread over the entire Texas coast at midnight.

As soon as the morning reports from the Texas coast were received, the following warning was sent to Texas coast stations and displaymen:

Advisory, 8:20 a. m.: Gulf storm now near south coast of Texas. Continue all precautions Sunday and Sunday night against dangerous winds and high tides from mouth of Sabine River to Brownsville.

Points on the Louisiana coast were advised of this warning and were notified that there was no further danger on the Louisiana coast.

The 10 a. m. (eastern standard time) report from Corpus Christi showed a barometer reading of 29.14, with a north wind of 36 miles an hour and a maximum velocity of 48 miles an hour from the north. The San Antonio and Houston offices were advised promptly that the storm center was near Corpus Christi and the barometer reading at 10 a. m. was given them. The 1 p. m. and 3 p. m. special observations, which had been called for, were not received from Corpus Christi on account of the wires being down. At 7:50 p. m. the following message was sent to Galveston and Port Arthur:

Storm passed inland near Corpus Christi, where barometer 29.14 at 10 a. m. Warnings may be lowered after gale subsides.

Central standard time is used in this report except in the reference to special observations at Corpus Christi.—
R. A. Dyke.

CONDITIONS AT GALVESTON.

This storm caused high winds and tides in the Galveston district. Fortunately, we were able to take precautions to some extent in this district, especially in the vicinity of Galveston, and the damage resulting from the storm was largely reduced to a minimum.

The storm was first reported on September 3, 1919, "near and south of Porto Rico," and bulletins showing the progress of the storm were received daily, except on September 6 and 7. These bulletins were given a wide and effective distribution by means of the press, the telephone, telegraph, and the radio.

The storm entered the Gulf on September 9, and the first effect of the storm noted at Galveston was a slight, regular swell from the southeast that began to appear on the night of the 10th about 7 p. m. A light haze that developed about 2 p. m. the 10th continued until the lower clouds that formed late on the afternoon of the 13th finally did away with the hazy condition. Cirrus clouds coming from the tropical storm made their appearance on the morning of the 11th and continued until the lower clouds finally obscured them. These cirrus clouds were observed moving generally from the southeast. On the 13th alto-cumulus, moving mostly from the northeast, were the predominating upper clouds. During the afternoon of the 13th strato-cumulus clouds made their appearance, and by sunset the sky was practically covered by these lower clouds. From this time these lower clouds continued until the storm was over, interspersed with quickly moving scud.

A moderate rainfall accompanied the storm, a trace falling on the 13th shortly after 7 p. m., and showers on the 14th, 15th, and 16th, the total rainfall for the storm amounting to 2.35 inches.

Northerly winds prevailed on the 10th, 11th, 12th, and 13th. At times on the 10th and 11th the wind was from the northwest, and from the northeast on the 12th. During the morning of the 13th the wind prevailed from the north, but with a northeast tendency. By 2 p. m. on the 13th the wind was definitely from the northeast, and continued so until the wind shifted to easterly at about 6 a. m. on the 14th. At 2 p. m. on the 14th the wind shifted to southeast, continuing from this direction until the storm was over.

The winds were generally light until the 12th, when moderate winds prevailed during the afternoon and night. During the 13th the winds ranged from moderate to fresh, becoming strong by mid afternoon. Verifying velocity, 32 miles per hour, was first reached at 4.23 p. m. and continued with slight lulls until about 4 a. m. on the 15th. The maximum velocity reached during the storm was 53 miles from the east at 7.23 a. m. on the 14th, the extreme velocity being 60 miles.

The regular diurnal fluctuations of the barometer was present during practically the entire period of the approach of the storm, though the fall was more pronounced than the rise. The barometer had fallen below normal by the 10th and reached its lowest point at 4.30 a. m. on the 14th with a reading of 29.58 inches. On the night of the 12th there was a rather marked increase in the barometer reading, probably caused by the southward and eastward drift of a high-pressure area to the north-westward of the station. *This development undoubtedly prevented any recurring of the tropical storm and tended to prolong the westward movement of the storm area.*

There was a gradual increase in the intensity of the swells produced by the storm until they became the heavy, frequent swells that prevailed during the late afternoon of the 13th and continued during most of the 14th, dashing high above the sea wall, as the great volume of water was hurled back into the Gulf. There was the usual ebb and flow of tide until the afternoon of the 13th, when the tide began to come in steadily, from which time there was a regular and steady increase in the height of the tide until it reached its highest point of 8.8 feet at 7 a. m. of the 14th. The tide was above normal from about 4 p. m. of the 12th, though there were slight fluctuations as the ebb and flow occurred. From the time the highest tide was reached there was a gradual fall in the tide, though during most of the week following the storm the tide was generally considerably above normal.

As the tide began to rise rapidly late on the 13th, the water began to back in from Galveston Bay, covering the streets in the business section of the city. The low places down the island were flooded by the rising tide. By 7 a. m. of the 14th the streets in the city were covered with water to a depth of from 2 to 3 feet or more, that portion of the city lying north of Avenues F and G being under water, while the low portions down the island were from 4 to 5 feet under water.

The office was besieged with anxious inquirers during the entire week beginning the 8th, the office being kept open until midnight on the 8th, 9th, and 10th, and all night on the succeeding nights. The telephone was kept constantly busy, and bulletins were posted on the board at the entrance of the building in which the office is located. The telephone at the residence of the official in charge was also kept busy during much of the period, members of the family giving out official information as to the storm. On Saturday, the 13th, it being impossible to handle all inquiries on the telephone, the manager of the telephone company placed at the disposal of this office several operators who were given the official bulletins and information. With the aid of these operators we were able to supply information much more quickly and satisfactorily, the congestion of the office telephone being thus relieved.

On Friday, the 12th, as a precautionary measure, the railroad officials were advised to move the cars of grain and other perishable freight to places of safety on the mainland, there being about 3,000,000 bushels of grain on the tracks in Galveston. People owning cattle down the island and the business men generally were advised at this time to arrange to get their stock and goods in places of safety by Saturday. This advice was repeated on Saturday and people were informed that while the storm would probably not strike Galveston, it would undoubtedly cause high tides and high winds in this vicinity. People were told on Saturday that the weather map showed that the storm had not yet gone inland and that until it had definitely passed inland it was best to take all possible precautions.

As conditions began to become more threatening on the 13th, large numbers of people left town, trains and interurbans being crowded to capacity. People living in exposed places were advised to come into town until the storm was over. The city authorities cooperated in spreading this information and bringing the people to places of safety. All precautions were taken for safety. On Saturday night all coast territory was advised to take protective measures, use being made of the telephone, telegraph, and radio. Because of the closing of some of the offices, however, it was impossible to reach several

points, but by midnight all points that it was possible to reach had been given this advice.

Owing to the precautions taken, the property damage was slight in this immediate vicinity. Some damage was done outside the sea wall where the East End Fishing Pier, at Sixth and Boulevard, was destroyed by wave action. The concrete approach to the beach at Thirty-fifth and Boulevard was broken by having the rip rap hurled against it by the water. The United States Engineer Office was able to save the machinery used in building the extension to the sea wall on the flats east of the city, but lost some lumber that they had stored at Fort Point and some forms used in connection with the sea wall. From 3,000 to 4,000 bales of cotton, mostly from the Moody Press, floated away as the water rose and had to be salvaged. There was practically no loss of live stock here, as all the cattle had been brought from points down the island to places of safety in town. Some few hogs and some poultry that could not be located and collected were lost. Business men in town lost very little from the storm, as they had practically all taken precautions and had raised their stocks above the level of the water. The causeway connecting Galveston with the mainland suffered no injury, though the sand-filled approach to the causeway was washed, undermining some 1,700 feet of railroad track. This damage was soon repaired, and railroad and interurban traffic was resumed at 5 p. m. on September 15.

Two men lost their lives in the storm in this immediate vicinity, one a fisherman who was camping on the low flats east of the city and the other another man, probably a fisherman, who lost his life on the shore of the mainland opposite the middle portion of Galveston Island. Both men were apparently overtaken by the rising tide and drowned. So far as is known, there were no other lives lost in this storm-warning district from the hurricane.

From reports received the height of the tide accompanying the storm ranged in this district from about 4 feet at Orange, Tex., to approximately 13 feet at Port O'Connor, Tex. With this tide and the high wind accompanying it, some damage resulted at many points, especially along the water front. At Seabrook, Tex., there were a few buildings, mostly light structures, destroyed. At Texas City, Tex., there was little damage of consequence done. At points to the south of Galveston, however, there was more damage done. At Velasco and Freeport, Tex., there was some damage done, but I have been unable to get any report of the damage in detail. At Matagorda, Palacios, and Port Lavaca, Tex., there was considerable damage to wharves, fish houses, and small boats. Similar damage resulted at Port O'Connor, Tex., where several small houses were swept away. At Palacios the bathhouses and several small pavilions at the B. Y. P. U. encampment grounds were destroyed. The following estimate of property loss and damage in this district is given:

Seabrook, Tex.....	\$2,000
Galveston, Tex.....	60,000
Velasco and Freeport.....	10,000
Matagorda.....	30,000
Palacios.....	10,000
Port Lavaca.....	100,000
Port O'Connor and Seadrift.....	40,000
Total.....	252,000

To the north and east of Seabrook there was slight damage done by the storm, though the Gulf & Interstate Railroad suffered a series of washouts in the vicinity of

Carlen. It is estimated that the damage to the railroad will approximate \$20,000. This, added to the total given above, increases the total damage in this district to \$272,000. All these estimates of the amount of damage are only approximate and they may be subject to change.—A. H. Scott.

THE HURRICANE AT CORPUS CHRISTI.

All day of September 13, 1919, there were upper clouds in the sky. They were mostly cirrus and alto-cumulus, but with occasional patches of cirro-cumulus and a few banks of alto-stratus. The cloudiness varied from almost no clouds at all at times to eight-tenths cloudy at other times. These clouds were moving from almost due east all the time. In the evening, the alto-cumulus clouds covered the sky and did not disappear until the approach of the heavy nimbus clouds.

In spite of a steady north wind, the weather was very oppressive all day. The water in the bay was rather high and rising somewhat in the evening, which appeared unusual, as we ordinarily have low water with north winds.

During the late afternoon of that day, some persons on the roof of the six-story hotel at Rockport, Tex., observed a dark line along the eastern horizon. They watched the dark line till nightfall, during which time it rose slowly and appeared as a dark gray band along the eastern portion of the sky. They report no fringing cirrus or cirro-stratus clouds.

A party of workmen on St. Josephs Island report that between 10 a. m. and noon of the 13th the sea began to rise and became very choppy. By 2 p. m. the tide had risen so much that they left the island and went to Rockport. An hour or two later similar conditions were noted at Port Aransas and by a little after sunset the tide had reached 5 feet above mean sea level.

At all places along the coast unusual swarms of flies were noted on the 13th, and that these flies were very troublesome and persistent in sticking persons and animals has been frequently mentioned.—C. E. Heckathorn.

The following extracts from the Houston Post, September 19, 1919, give a picture of the experiences of the people and other effects of the storm:

Stretching along the beach for 23 blocks homes were crushed and hurled away or wrecked by the tidal wave, which reached a depth of 15 feet in some places. Over much of the beach section [on the point north of Weather Bureau office, see fig. 1] not an indication of former homes now remains, except here and there a bathtub or part of a brick chimney.

From Star Street, where the business section on the beach terminated, to Dan Reid Street every one of the 900 beach homes has been destroyed, most of them beyond trace, while here and there a mourning palm tree hanging low, its oil-begrimed leaves marking the spot of some former show place. In this section the bay line has changed, the water having established a new line varying from 50 to 200 feet inland from the former position. This change extends from the business district to the end of the north beach and out as far as Carroll Street, a distance of eight blocks.

* * * In the downtown district utter demolition of some of the city's most important industrial and public plants marked an area extending for six blocks along the water front and more than a block in width, while beyond that block, extending back toward the bluff section, every commercial establishment's first floor was wrecked, and in some cases the entire building rendered useless, over a corresponding area two blocks wide.

The tremendous property damage is becoming daily more apparent and prominent business men and other trained observers predicted to-night [Sept. 18] that \$20,000,000 would be a conservative estimate of the monetary loss in Corpus Christi.

284 bodies, almost entirely those of Corpus Christi victims, have been found in the following places and buried:

Corpus Christi.....	57
White Point.....	121
Rosita and Portland.....	80
Oden and Sinton.....	11
Port Aransas.....	5
Aransas Pass.....	2
Rockport.....	8

* * * Details of conditions at Port Aransas and other parts of the islands between Corpus Christi Bay and the Gulf were ascertained Thursday by Regular Army aviators who flew over that territory. Their survey was confirmed by Capt. Max Luther, collector of customs at Port Aransas. The docks and buildings in Port Aransas have been wiped out with the exception of a school building, and three vessels—the steamer *Median* and two large tankers, the *Juanita* and *Susquehannah*—were reported “high and dry” upon the island. The large oil tanks there also were destroyed. * * * The five who lost their lives [at Port Aransas] were drowned while attempting to leave the island in a lifeboat.

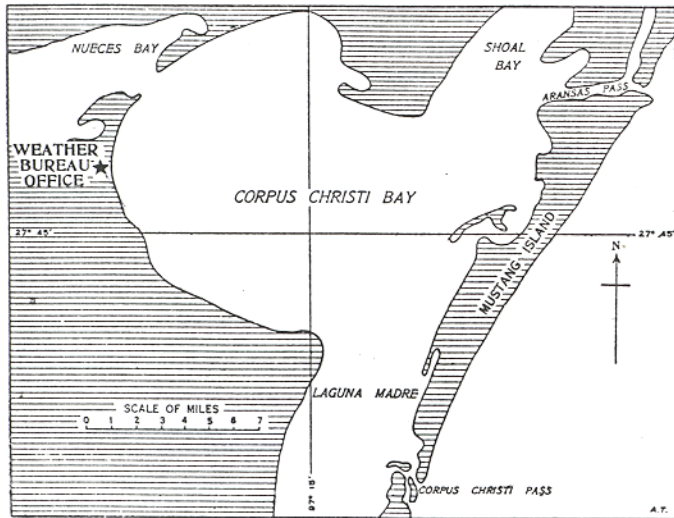


FIG. 1.

* * * As the water came in, an old captain, who has charge of some Government boat there [at Port Aransas], steered his ship in over the island toward the sand ridges where the people were perched hunting safety. As the water rose he went still farther in, stowing the folks away on his ship, sailing over the island from one sand hill to another.

* * * Of the many tales of personal heroism none that has come to light exceeds that of Esther Fuller, 17 years of age.

Esther and her 9-year-old brother Ted, were swept into the tidal wave when their home was carried away during the height of the storm Sunday afternoon. The boy was hit by a piece of debris while struggling in the water and rendered unconscious.

The girl grabbed him just as he started down and began her battle with the wind and waters. Making use of every bit of driftwood and wreckage that came her way she struggled on, sometimes clinging to a housetop, and at others only [to] a board. At other times she was forced to swim until almost exhausted before another piece of wreckage came within her reach.

For 5 miles she fought the hurricane and the waves. She and her brother were finally washed ashore on the opposite side of the bay [near Sinton] where they were found [alive] early Monday morning.

ANAHUAC, MEXICO, September 18.—The Gulf storm caused a 6-foot tide here, but Anahuac is situated on a 25-foot bank of Trinity Bay, hence no damage was done. The wind reached a velocity of perhaps 30 miles. The bulkhead across Trinity Bay was damaged, the fill at one end near the lock being washed out.

PATH OF THE HURRICANE.

The path of the hurricane, as nearly as it could be computed, is shown on Chart II. It was compiled from all available information, much of which was received some time after the storm. It will be seen from the chart that the first indication of the disturbance can be noted on the evening of September 6, probably about 130 miles west-northwest of Turks Island, West Indies, but

it was not until the receipt of a belated report on September 8 that a severe storm could be located south of and near the Andros Islands. After the morning of the 10th, at which time the storm center was apparently very near Dry Tortugas, Fla., its path could only be approximated. It happened, however, that a report received by mail from the steamship *Lake Deval* nearly two weeks after the storm located the center with a fair degree of definiteness on the morning of the 12th of September, and its position nearly coincided with the estimated position given out on that morning. Attention is invited to the fact that the storm center was about eight days in traveling from the eastern Bahamas to the interior of extreme southern Texas, a remarkably slow, and in this respect a probably hitherto unprecedented, rate of movement.

This storm was only the second September storm of this character of any consequence that reached the south Texas coast during the last 45 years, the other having occurred in 1910. The storm of 1919 was by far the more violent of the two, and was probably the greatest of all Gulf storms. The entire absence of radio reports from vessels in the Gulf was the first instance of the kind since the establishment of the vessel-reporting service some years ago, and, while this fact might be considered as a tribute to the efficiency of the Weather Bureau Service, it was nevertheless a source of considerable embarrassment to the forecaster, as he was obliged to base his conclusions entirely upon observations far removed from the storm center, with consequent probability of a certain amount of error, which probability was reflected in the widespread character of the warnings, which would have been localized much more definitely if some definite radio information had been available. As one press report had it, “The Weather Bureau suffered from its own efficiency.” The adoption of measures that will effectively prevent a repetition of this occurrence presents a question that must receive early consideration.

BAROMETER READINGS DURING THE STORM.

The barometer readings near and at the center of the storm were almost unprecedentedly low, although at Key West, which was only about 30 miles north of the center as it passed, the lowest sea-level reading was only 28.83 inches, whereas during the hurricanes of 1909 and 1910 the lowest readings at that place were 28.52 and 28.47 inches respectively. At the Sand Key station, about 8 miles southwest of Key West, and consequently about an equivalent distance nearer the storm center, the lowest barometer reading was 28.35 inches. Even if no other evidence were available, the difference of 0.48 inch over the 8 miles between Key West and Sand Key would indicate that at the center of the storm the pressure was very much lower, and later readings obtained by mail from other sources, including vessels in the Gulf of Mexico, afforded positive confirmation of the fact. In his report the official in charge at Key West stated that the center of the storm passed directly over Dry Tortugas, 65 miles west of Key West, with a reported barometer reading of 27.51 inches, while at Rebecca Shoals Light, about 40 miles west of Key West, the lowest reading was 27.66 inches. The barometers at these two places were later compared with another instrument whose correction was known, and the observed readings corrected accordingly. The steamship *Winona* went ashore at 10 a. m., September 10, on a reef on the north-east portion of the Tortugas group, near Pulaski Shoals. She had been in that vicinity for at least 18 hours, and

from 12 noon until 4 p. m. of the 9th the barometer fell from 29.40 to 27.70 inches, a fall of 1.70 inches in four hours. From 4 p. m. to midnight there was a further fall to 27.45 inches, or a total fall of 1.95 inches in 12 hours. These three readings, differing but 0.21 inch within a very limited area, make it safe to assume that they were substantially correct. A later report from the tank steamer, *Fred W. Weller*, showed a barometer reading of 27.36 inches in the vicinity of Dry Tortugas on September 9. It is understood that the barometer carries a Weather Bureau correction. The only other readings from the vicinity of the storm center also came by mail, and were as follows: Steamship *Lake Deval*, at 9 a. m., September 12, in latitude 26° 10' north, longitude 87° 50' west (approximate), 27.89 inches; steamship *Lake Grandon*, at 4 p. m., September 12 (exact position unknown, but doubtless somewhere near latitude 27° north and longitude 89° west), 27.99 inches; steamship *Tegucigalpa*, at 5 p. m., September 12, latitude 26° 58' north, longitude 88° 30' west, 27.81 inches; another report received by mail on October 29 from the captain of the steamship *Berwyn* stated that his vessel passed through the storm center at midnight of September 12, at latitude 26° 30' north, longitude 90° 30' west, with a barometer reading of 27.50 inches; steamship *F. R. Kellogg*, at 9 a. m., September 14, latitude 27° north, longitude 95° west (approximate), 28.07 inches. No other readings were obtained from the Gulf of Mexico, and the next available ones were from the Weather Bureau stations on the Gulf coast. The lowest readings were 28.65 inches at Corpus Christi, Tex., a short distance north of the storm center, at 3 p. m., September 14; 29.13 inches at Brownsville, Tex., at 1 p. m., September 14, and 29.65 inches at Galveston, Tex., at 12.30 a. m., September 14. The lowest barometer reading reported was that of the steamship *Fred W. Weller*, 27.36 inches.

At Habana, Cuba, on October 11, 1846, a barometer reading of 27.06 inches was reported,¹ and there is a record of 26.85 inches at Morne Rouge, Island of Martinique, on August 18 or 19, 1891.² The character and accuracy of the barometer from which the latter reading was made is not known, but, assuming that the reading was accurate, it is doubtless the lowest reading of record for the Western Hemisphere.

Wilhelm Krebs, in the article before quoted, makes mention as follows of two still lower barometer readings, both in the Eastern Hemisphere: At Vohemare, on the coastal lowland of northeastern Madagascar, on February 3, 1899, 24.76 inches, and on board the steamship *Arethusa*, latitude 13° 35' north, longitude 134° 30' east, on December 16, 1900, 26.16 inches.

STORM EFFECTS.

Except on the south Texas coast, the land damage was slight. The full force of the storm was experienced between Aransas Bay and the mouth of the Rio Grande, where the high tides resulted in a toll of 183 dead and 174 missing. It is probable that some of the missing were also listed among the unidentified dead, and, if so, the total casualties will be somewhat reduced.

Along the Mississippi coast the highest tides of the season were experienced, but the winds were not unusu-

ally high, and there was little or no damage reported. At Pensacola, Fla., the highest wind velocity reached was 40 miles an hour from the east during the afternoon of September 13. At Tampa, Fla., the maximum wind velocity reported was 34 miles an hour from the northeast during the late afternoon of September 10, and on the following day the tide reached a crest of 5.55 feet above low-water mark, 2 feet higher than ever before recorded in the annals of the United States Engineers. The tide did some little damage along that section of the coast, but none of consequence. No high winds were reported at Fort Myers, Fla., the only Weather Bureau station between Tampa and Key West.

The storm history at Key West and Sand Key will be found in the reports of the officials at those stations. At Miami, Fla., the highest sustained wind velocity reported was 46 miles an hour from the east during the late afternoon of September 9, and the gale continued during the day following. During its prevalence there were occasional gusts that reached a velocity of 60 miles an hour. Considerable local damage was done in Miami and vicinity, although nothing very serious resulted. Tides were unusually high and many small boats suffered. The greatest loss was probably in the fruit crop, marketing of which had already begun. Press reports indicated that considerable damage was also done along the northwest coast of Cuba.

Some damage to shipping was, of course, to be expected, but in spite of the great intensity, size, and duration of the storm only ten casualties of major character and 25 minor ones have been reported. The greatest of these was the loss of the Spanish steamship *Valbanera*, off Rebecca Shoals Light, about 40 miles west of Key West. The vessel arrived off Morro Castle, Habana, on September 9, but owing to the hurricane, was unable to enter the harbor, and nothing further was heard from her until a diver discovered her beneath the waters off Rebecca Shoals. The *Valbanera* was from Spanish ports for New Orleans, via Habana, and her 400 passengers and crew of 88 must have perished.

The other wreck was that of the Ward Line steamship *Corydon*, on the morning of September 9, in approximately latitude 24° north, and longitude 79° west. Of the crew of 37 men, 27, including the captain, went down with the boat. Ten men escaped in a lifeboat, and nine of them were picked up two days later at Cape Florida, a few miles south of Miami. The tenth man, who became insane while in the boat, was washed overboard. The lowest barometer reported by the *Corydon*, through Third Officer B. L. Mallows, who was one of those rescued, was 28.34 inches at 11 p. m., September 8.

As regards the losses of or damage to vessels (Tables 1 and 2) it will be noted that none had left port after storm or hurricane warnings had been issued, i. e., after the 8th from Florida ports or after the 10th from other Gulf ports. Of those which had sailed earlier it is not stated how many did or could have received warnings by radio.

An aftermath of the storm was a tornado that swept through the business district of Goulds, Fla., a small town south of Miami, about 1 p. m., September 10. The center of the tropical storm at that time was probably about due west of Goulds, at some considerable distance. (See account on p. 639.)

¹ Marcus T. Melero, *Diario de la Marina*, Oct. 9, 1873.

² Krebs, *MONTHLY WEATHER REVIEW*, March, 1911, 39: 471.

TABLE 1.—Vessels reported lost or missing (extracted from *New York Maritime Register*, September to October, 1919).

Vessel.	Nation.	Reg.	From—	Date.	Last seen.	Date.	Bound for—	Remarks.
Bayronto.....	Brit.....	S. S.....	Galveston.....	Sept. 6			Marseille.....	Foundered Sept. 13 in latitude 26° 45' N., longitude 83° W.; 19 of crew rescued by S. S. Calno.
Copperfield.....	Amer.....	Schr.....	Mobile.....	Aug. 25				Abandoned near Rebecca Shoal Sept. 11; crew saved. Subsequently towed to Tampa.
Corydon.....	Amer.....	S. S.....	Antilla.....	Sept. 6				Foundered in Bahama Channel, Sept. 9, with loss of 27 lives. One boat of survivors.
Hugh de Payens.....	Amer.....	Schr.....	Mobile.....				Pon-e.....	Wrecked in Florida Straits. Crew rescued by S. S. Olinda.
Lake Conway.....	Amer.....	S. S.....	Philadelphia.....	Sept. 2			Habana.....	Due at Habana Sept. 10. Crew of 31.
Larimer.....	Amer.....	Tank S. S.....	Port Arthur.....	Sept. 5	Off Key West.....	Sept. 8	Baltimore.....	Reported "missing" in N. Y. Maritime Register of Nov. 5.
Maud H. Dudley.....	Amer.....	Schr.....	Pensacola.....	Aug. 31			Habana.....	Abandoned 40 miles off Habana Sept. 13. Crew rescued by S. S. Lake Leelanau. Picked up 17th by fishermen off Knights Key, dismantled and full of water.
Munista.....	Amer.....	S. S.....	Mobile.....	Sept. 8			Habana and Pensacola.....	Lost in Gulf about Sept. 10.
Preston.....	Norweg.....	S. S.....	New Orleans.....	Sept. 9	Anchored below New Orleans.....	Sept. 10	St. Jago.....	
Valbanera.....	Span.....	S. S.....	Barcelona.....		Off Habana harbor.....	Sept. 9	Habana.....	Sank near Half Moon Key on Sept. 11 (?). No survivors of large crew and passenger list.

Two schooners reported to have gone down on Cat Island, Bahamas, with all on board.

TABLE 2.—Vessels damaged by the hurricane (extracted from *New York Maritime Register*, September to October, 1919).

Vessel.	Nation.	Reg.	From—	Date.	Bound for—	Remarks.
A. C. Bedford.....		Tank S. S.....	Port Lobos.....	Sept. 5	Baltimore.....	Considerably damaged. Lost 8 boats, sprung a leak and lost about 5,000 tons of oil.
Calno.....		S. S.....	Mobile.....	do.....	Amsterdam.....	Put into Charleston Sept. 16, with deck and engine room damaged and deck load lumber shifted. Rescued 19 members of crew S. S. Bayronto. Returned second time to Charleston to repair machinery.
Comal.....		S. S.....	Galveston.....	Sept. 6		Aground at Key West. While aground was rammed by U. S. S. Wheeling.
Delmira.....	Brit.....	Tank S. S.....	New Orleans.....	Sept. 8	Antilla.....	Sept. 19, put back into New Orleans for repairs after damage in severe gale [hurricane].
Edward Sewall.....		Ship.....	Port Arthur.....	Sept. 6	La Plata.....	Broke from tow and sustained considerable damage. Returned to Port Arthur on 13th.
Elizabeth Bandi.....		Schr.....	Gulfport.....	July 13	St. Thomas.....	Arrived St. Thomas Oct. 23. Reported captain drowned during heavy weather.
El Mar.....		S. S.....	New Orleans.....	Sept. 9	New York.....	Put into Key West Sept. 12 to restore cargo.
Flavel.....		S. S.....	Galveston.....	Sept. 6	Helsingfors.....	Put into Key West damaged. Proceeded Sept. 14 to Jacksonville for repairs.
Fred W. Weller.....		Tank S. S.....	Tuxpam.....			Arrived Key West Sept. 12, damaged during hurricane.
Gartyrna.....	Greek.....	S. S.....	New York.....	Aug. 20	Sagua.....	Put into Jacksonville Sept. 13 for repairs.
Gullflight.....		Tank S. S.....	Port Arthur.....	Sept. 9	Jacksonville.....	Arrived at Jacksonville with all stores destroyed and one tank leaking.
Hillsboro County.....		S. S.....	Habana.....	Sept. 8	Cardenas.....	Driven ashore on north Cuban coast Sept. 9. Crew saved.
Hornet.....		S. S.....	Bluefields.....		Pensacola.....	Sustained slight damage and loss of part of deck load.
Lake Duane.....		S. S.....	Mobile.....	Sept. 5	Habana.....	Put into Key West, Sept. 12, damaged, but proceeded.
Lake Grandon.....		S. S.....	New Orleans.....	Sept. 10	Hull.....	Returned to port in distress.
Lake Winona.....		S. S.....	do.....	Sept. 7	Porto Rico.....	Went ashore on Dry Tortugas during hurricane, but subsequently towed into Key West. Bottom reported badly damaged.
Ligonier.....		Tank S. S.....	Port Arthur.....	Sept. 6	Savannah.....	Machinery disabled, lifeboats, ventilators, and wireless blown away. Lost tow barge Monongahela.
Median.....	Brit.....	S. S.....	Liverpool.....	Aug. 20	Port Aransas.....	Lifted on apron of wharf at Port Aransas during hurricane. Later floated undamaged.
Monongahela.....		Oil barge.....	Port Arthur.....	Sept. 6	New York.....	In tow S. S. Ligonier. Broke tow but later picked up. No damage; crew safe.
Palafox.....		Aux. schr.....	Santa Cruz, Cuba.....	Aug. 28	Tampa.....	Partially disabled and put into Gulfport on Sept. 17 for repairs.
Randolph S. Warner.....		S. S.....	Philadelphia.....	Sept. 5	Houston.....	Went aground near Hillsboro Lighthouse; subsequently refloated.
Tonawanda.....	Brit.....	Tank S. S.....	Barry.....	Aug. 9	Tampico.....	Broke away from dock and went ashore in Key West Harbor, Sept. 9.
U. V. Drew.....	Brit.....	Schr.....	Tampa.....	Sept. 8	Sagua.....	Arrived Key West on Sept. 9 in sinking condition.
War Jandoli.....	Brit.....	Tank S. S.....	Port Arthur.....	Sept. 4	Hull.....	Went aground at Key West night of Sept. 8. Got off next night and went ashore on Crawford Bar.
War Mogul.....	Brit.....	Tank S. S.....	do.....	Sept. 6	Lough Swilly.....	Put into Habana, Sept. 11, with cargo leaking into double bottom.

THE WEST INDIA HURRICANE OF SEPTEMBER, 1919, IN THE LIGHT OF SOUNDING OBSERVATIONS.

By R. HANSON WEIGHTMAN, Meteorologist.

[Dated: Weather Bureau, Washington, Dec. 3, 1919.]

The hurricane of September, 1919, is the first well-developed storm of tropical origin in connection with which sounding observations of wind directions and speeds in the free air are available for study purposes. In 1906 and 1907 while Rotch and de Bort were conducting sounding balloon and kite work¹ in the southeastern portion of the North Atlantic Ocean several disturbances of minor importance occurred in the West Indies but, unfortunately, many hundred miles away from the point where observations were being made. Again in the early part of August, 1918, a disturbance of intense character but of very limited extent developed in the Gulf of Mexico and passed inland west of New Orleans during the 6th. The nearest point to the storm at which sounding observations are available is Fort Sill, Okla., about 500 miles distant. On the mornings of the 5th and 6th at this station the winds up to the greatest elevation reached, the 2,000 meter level, were from the SW., 10 to 18 m. p. s., and at noon of the 6th they had backed to SSW. and decreased somewhat in velocity, seemingly unaffected in any way by the disturbance.

In the September, 1919, hurricane upper-air observations are available from three stations in Texas, two in Oklahoma, one in Georgia, and from nine or ten other stations outside of the Gulf States. The most complete series of observations from a point relatively near the hurricane center is from the Leesburg, Ga., station, the nearest point reached by the storm center, however, being about 500 miles. At the time the disturbance was approaching southern Texas, the sky over that region unfortunately became overcast for the most part, thereby preventing the making of observations at greater altitudes than 3.5 km. and in most cases under 2.

Perhaps the most interesting feature brought out by these observations is the rather sudden change in wind direction as shown by sounding balloons at Leesburg. For several days previous to September 5, the winds above 3 km. were from a westerly quarter while near the surface they were between north and east. On the 1st westerly winds were first encountered at the 2 km. level, on the 2d at the 3-km. level, on the 3d at 3-km., on the morning of the 4th they had descended to 2 km. and by evening had risen to 3.5 km. On the morning of the 5th they were first observed at the 4-km. level and by the afternoon of that date were not in evidence up to 11 km., the greatest altitude reached. So far as observations are available, no trace of westerly

winds is found until the morning of the 12th, when they were encountered at an elevation of 6 km., and by the afternoon of that date they had descended to 4.5 km. This shift of the upper winds to W. and N. seems to have been of a temporary character, for on the 15th they were generally between ENE. and ESE. up to 11 km., and it was not until the 16th that they changed to steady westerly.

A current from the east was then fully established at Leesburg at all altitudes up to probably 10 km., at least, from the evening of the 5th to the morning of the 12th, a rather unusual occurrence, if we may judge from a casual inspection of the observations made during the two or three preceding months. In the lower strata, at least, this distribution of winds is consistent with the surface barometric distribution, for during the time of the prevalence of the easterly winds pressure was relatively high over the southern Appalachian region and the interior of the east Gulf States and relatively low to the southward. The persistence of the easterly winds in the upper layers, however, appears to be quite unusual. This easterly current is also in evidence up to the 5 km. level at the south Texas stations, i. e., Groesbeck, Ellington Field near Houston, and Kelly Field near San Antonio, from the 1st of the month until the time the hurricane crossed the Gulf coast about 50 miles south of Corpus Christi on the 14th. The highest levels shown by the observations do not exceed 5 km. except in two cases; one on the morning of the 5th at Kelly Field, showed winds between N. and NW. between 5 and 10 kilometers. This easterly current seems to have a rather well-marked limit, for the stations at Broken Arrow and Fort Sill, both in Oklahoma and less than 500 miles to the northward, showed a number of observations between the 5th and 10th of the month, in which the winds were from a westerly quadrant. Likewise, with the easterly winds observed at Leesburg, the northern boundary must have been quite well defined for the sounding observations at Washington about 750 miles distant show practically all winds from a westerly quarter. The southern limit of the easterly current is rather difficult to determine, but an examination of the cloud observations at Swan Island, Belize, and Bluefields shows that easterly winds prevailed in the cumulus level (about 2,000 meters) up to the 8th. During the 4th a minor disturbance passed over Santo Domingo, advanced northwestward to the west of Turks Island by the morning of the 5th, and from that point recurved to the northeastward. On the evening of the 6th after the passage of this disturbance the winds over Jamaica in the cumulus level were southerly, over Haiti southeasterly,

¹ Etude de l'atmosphère marine par sondages aériens; Atlantique moyen et région intertropicale. Par Mm. L. Teisserenc de Bort et Lawrence Rotch. Travaux Scientifiques de l'observatoire de Météorologie Dynamique de Trappes. Tome IV.

and over Porto Rico easterly (see fig. 1), and the wind at Turks Island had backed to the southeast, indicating the presence of a second disturbance to the southwest or westsouthwest of that point. Fig. 1 shows a circulation of considerable extent with S. to SE. winds on the south side and NE. winds on the northwest side, which is the earliest recognizable stage of the hurricane. Figs. 2, 3,

It would seem that the wind conditions depicted on fig. 1 are a good illustration of the principle stated in the above extract.

An inspection of the means of the velocities at Leesburg at the 2,500-, 3,000-, and 3,500-meter levels during the hurricane are shown in fig. 5. These levels were chosen for the reason that it was believed a mean of

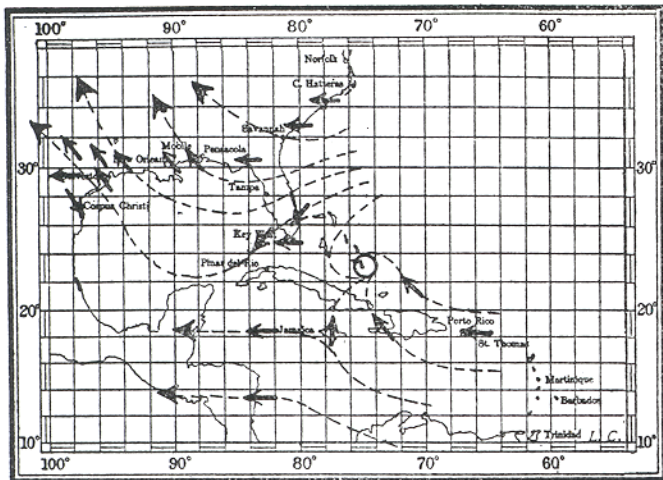


FIG. 1.—Instantaneous stream lines (2,000-m. level), p. m., Sept. 6, 1919.

and 4 show subsequent stages of the storm. The arrows indicate wind directions in the cumulus level (2,000 m.) as obtained from clouds and sounding observations. Instantaneous stream lines² have been drawn in order to bring out to the best advantage the existence of the countercurrents to the northwest and southeast of the area

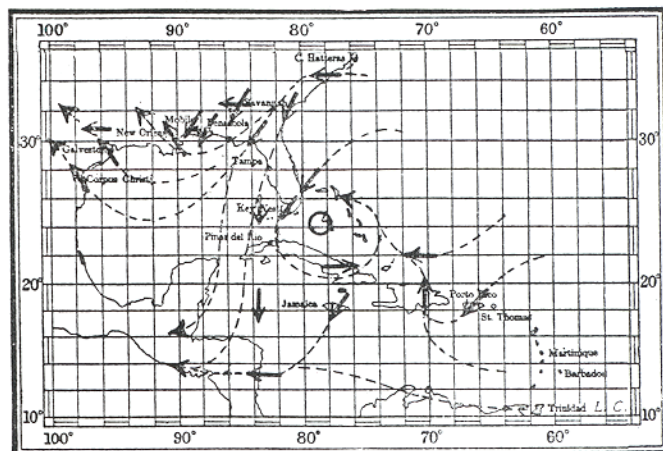


FIG. 3.—Instantaneous stream lines (2,000-m. level), p. m., Sept. 8, 1919.

them would be reasonably representative of the general air movement and secondly they were the highest levels at which a sufficient number of twice daily observations were available. It will be observed that winds were of small velocity, i. e., below 5 m. p. s. previous to the 6th and that from the evening of the 6th to the morning of the 10th they were greatest, averaging about 9 m. p. s., after

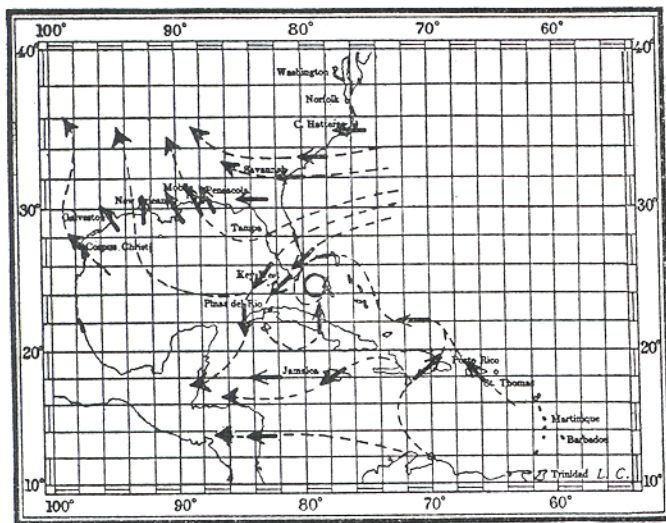


FIG. 2.—Instantaneous stream lines (2,000-m. level), p. m., Sept. 7, 1919.

where the storm developed. The small circles show the center of the hurricane.

On page 6 of MONTHLY WEATHER REVIEW, Supplement No. 4, Anticyclones of the United States and Their Average Movements, it is stated:

Likewise in the late summer and early fall months of the Northern Hemisphere hurricanes occur in the doldrums, a region flanked on the north by the northeast trades and on the south by the southeast trades, which latter on crossing the Equator and passing to an appreciable north latitude are deflected to the right and become southwest winds.

² The Life History of Surface Air Currents. By W. N. Shaw and R. G. K. Lempfert M. O. 174.

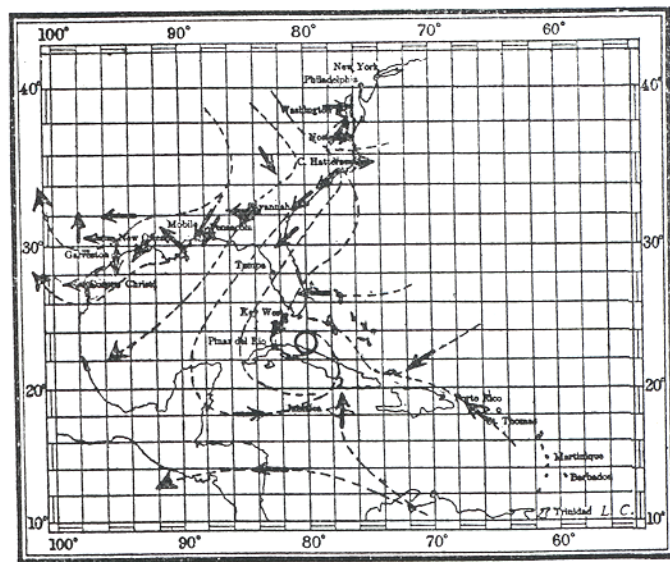


FIG. 4.—Instantaneous stream lines (2,000-m. level), p. m., Sept. 9, 1919.

which time they decreased to less than 6 m. p. s. At its inception the center of the hurricane was about 1,000 miles from the station and on the 10th it was about 500 miles distant. It is rather difficult to explain the fact that during the time the storm was nearest the station and while it was at its maximum development these wind velocities decreased to about half of what they were

when the storm was approaching its nearest point and before it had attained full intensity. However, having in mind the countercurrent theory of storm development, it is interesting to note that the high velocities of these easterly and northeasterly winds—little is available to show directions and velocities south of the center—preceded the increase in intensity of the storm and that a short time after these currents decreased to normal velocities the storm did not further increase in intensity. The storm was able to maintain its destructive violence for about 5 days after the easterly winds at Leesburg had decreased to normal velocities, after which time it

storm center.³ The following extract from Mr. Boyer's paper gives the underlying principle of atmospheric circulation in and around hurricanes as enunciated by Father Vines.

As a rule the lower currents converge, forming with the bearings of the storm center a variable angle which is almost always greater than

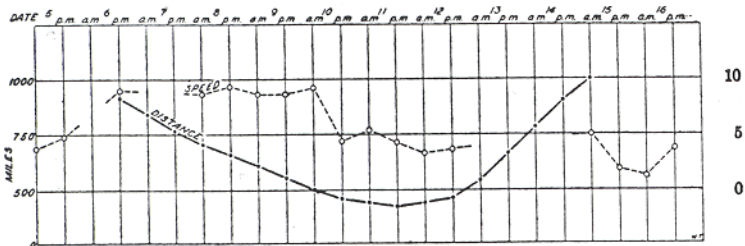


FIG. 5.—Distance of hurricane center from Leesburg, Ga. (solid lines) and mean of wind speeds at 2,500, 3,000, and 3,500 meter levels at Leesburg, Ga. (broken lines).

decreased in intensity. It is believed that, whatever be the cause of the high velocities noted, they were instrumental in causing the storm. The cause of the high easterly winds the writer is at a loss to explain. It has been suggested that the overflow of air from the storm may have had the effect of decreasing the barometric gradients aloft, thereby causing the winds to decrease as the storm approached the station. Observations of the vertical barometric gradients as obtained from the kite observations at Leesburg are somewhat meager. Observations

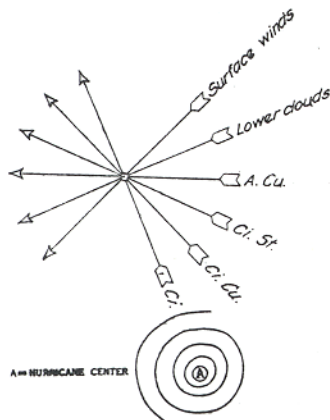


FIG. 6.—Direction of cloud movement with reference to direction of hurricane center.

are, however, available for the 3rd, 5th, 6th, 7th, 13th, and 14th but the gradients on those dates fail to explain the cause of marked increase in the wind velocities from the 6th to 10th and the decrease thereafter, the gradients between the surface and 1,000 meters, 1,000 to 2,000 and 2,000 to 3,000 being practically the same preceding, during, and subsequent to the increase in the winds.

It has been stated in connection with tropical storms that the direction of the winds at different elevations as evidenced by the movement of clouds, forms different angles with the line connecting the point of observation and the



FIG. 7.—Instantaneous stream lines (2,000-m. level), p. m., Sept. 11, 1919.

a right angle. * * * The lower clouds in the interior of a hurricane fly ordinarily in directions perpendicular to the bearings of the center. * * * The cumulus (high) (alto-cumulus?), cirro-stratus, cirro-cumulus and the cirrus clouds that precede the hurricane generally diverge, that is to say their direction forms with the bearings of



FIG. 8.—Instantaneous stream lines (4,000-m. level), p. m., Sept. 11, 1919.

the center an angle less than 8 points (90°) with the very noticeable peculiarity that if different strata are observed it will be seen that the divergence increases with elevation.

Fig. 6 which appears in both papers referred to shows the relative directions at the different levels. To test the

³ Atmospheric circulation in tropical cyclones, as shown by the movement of clouds H. B. Boyer, Washington, 1896. U. S. Weather Bureau publication, and West Indian Hurricanes, Benito Vines, Washington, 1898. U. S. Weather Bureau publication No. 168.

application of these principles to a storm in the Gulf of Mexico around which numerous observations are available, charts were prepared for several dates using the cloud observations and sounding observations, it being consid-



FIG. 9.—Instantaneous stream lines (6,500-m. level), p. m., Sept. 11, 1919.

ered that certain kinds of cloud were representative of certain elevations and four levels were adopted as follows:

Meters.	Cumulus.	Strato-cumulus.	Alto-cumulus.	Alto-stratus.	Cirro-cumulus.	Cirro-stratus.	Cirrus.
2,000	1,585	2,123					
4,000			3,656	4,572			
6,500					6,096	6,706	
8,500							8,534

The maps of September 11 are reproduced in figs. 7, 8, 9 and 10. From an inspection of these charts on which instantaneous stream lines have been drawn and on which the center of the hurricane is indicated by a small circle, it is apparent that the principles set out by Boyer and Vines are not entirely applicable to this storm, however well they may be adapted to conditions in the West Indies—nor do the charts for other days change this point of view. In this connection it is a fact that the winds at Leesburg on the morning of the 9th were NE. at every level from the surface up to 5 km. and NNE. at 6 km., the greatest reached, and on the afternoon of the 9th winds were NE. or ENE. up to 7 km., the highest level reached. This condition was also observed at Kelly Field on the afternoon of the 11th when the winds were NNE. from the 500-meter level up to 6 km. Again, at Broken Arrow on the 12th winds were NNE. up to 7 km. with the exception of two levels, namely, E. at 500 meters and NE. at 1,000. In other words, they had practically the same direction up to the limit of observations and were not observed to diverge with elevation.

It would further seem that these data are but another argument for setting aside the long cherished

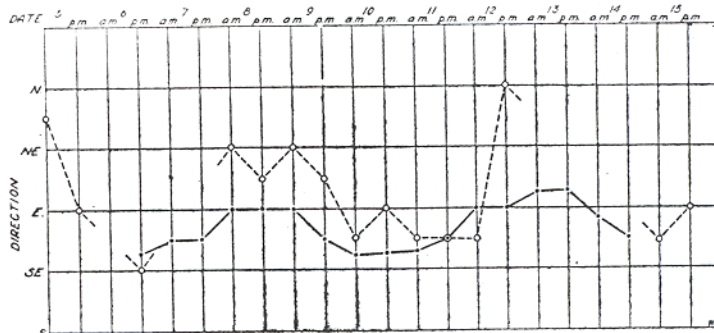


FIG. 11.—Direction of movement of hurricane (solid lines) and mean of wind directions at 2,500, 3,000, and 3,500 meters at Leesburg, Ga. (broken lines).

theory that in cyclones there is an outflow in the upper strata which is in effect anticyclonic.

Fig. 11 shows the wind direction at Leesburg, a mean being taken of the 2.5, 3.0, and 3.5 km.-levels, and the direction of movement of the storm center each 12 hours. It will be seen that they correspond in quite a marked degree, which would seem to indicate not necessarily that the storm was carried along in the drift of the easterly winds but rather that the storm passed westward along the southern boundary of the great easterly current.

The following extract from a paper by H. H. Hildebrandsson⁴ refers to statements by Clement Ley concerning the movement of cyclones in the Northern Hemisphere is pertinent in this connection:

However, if the steepest gradients are found to northwest, north or northeast of the center, it (the cyclone) most frequently remains motionless or moves (evidently slowly) in any direction, although a movement toward the west, which should then be found, is in reality relatively rare.

The movement of the September, 1919, storm was unusual in direction and in rate of movement, and, further, pressure was relatively high to the north of the center. The movement was unusual in that storms originating north of the Islands generally move north and northeastward, and the rate of movement was abnormally slow, in fact only about 200 miles a day, whereas the average for September storms approximated 250 miles a day, that is only about four-fifths the usual rate.



FIG. 10.—Instantaneous stream lines (8,500-m. level), p. m., Sept. 11, 1919.

The afternoon sounding observations were used together with the clouds recorded at 8 p. m., 75th meridian time, and when clouds were not available at that observation those observed at noon were employed, the 8 p. m. and noon observations being separated by a nearly equal time interval from the sounding observations.

On the morning of the 17th there was a disturbance off the southeast coast of Florida, and advisory warnings of possibly increasing winds were issued. Conditions became somewhat more pronounced by 8 p. m., and at 9:30 p. m. northwest storm warnings were ordered from Miami to Jacksonville, Fla., and northeast warnings to the northward as far as Georgetown, S. C. At the same time a disturbance from the Canadian northwest was central-north of Georgian Bay, with an apparent tendency toward increased development, and at 10 p. m. southwest-storm warnings were ordered from Cleveland, Ohio, to Oswego, N. Y., and strong winds occurred on the lower lakes on the 18th and extended northward over Lake Huron. The South Atlantic disturbance continued to develop, and at 11 a. m. of the 18th the northeast warnings were extended northward to Fort Monore, Va. By 8 p. m. there was a secondary disturbance over southern New England and northwest warnings were ordered from Sandy Hook, N. J., to Provincetown, Mass. Reports received by radio indicated the occurrence of gales a short distance off the South Atlantic coast, but no strong winds were reported from coast stations. Along the northern coast strong winds and gales occurred.

As the low pressure still persisted off the Atlantic coast northwest-storm warnings were ordered at 3 p. m. November 19 from Hatteras, N. C., to Atlantic City, N. J., to be lowered at 8 a. m. of the 20th, and at 7 p. m. the northwest warnings from Sandy Hook to Provincetown were ordered continued for another day. These warnings were fully verified.