

SECTION III.—FORECASTS.

FORECASTS AND WARNINGS FOR JULY, 1916.

By H. C. FRANKENFIELD, Supervising Forecaster.

[Dated: Weather Bureau, Washington, Aug. 1, 1916.]

GENERAL PRESSURE DISTRIBUTION OVER THE UNITED STATES AND CANADA, INCLUDING THE HAWAIIAN AND ALEUTIAN ISLANDS, ALASKA, AND THE MIDDLE ATLANTIC OCEAN.

Over the Hawaiian Islands pressure was somewhat above normal during almost the entire month of July, 1916, with a principal crest from the 5th to the 10th, inclusive, during which time pressure was also somewhat above normal over the Aleutian Islands and northwestern Alaska. With this exception moderately low pressure prevailed over the Aleutians and Alaska during the first three weeks of the month, followed by a moderate rise thereafter. The lowest pressure occurred about the middle of the month over the Aleutians and northwestern Alaska, but the condition did not extend in material form either eastward or southward.

On the whole the general pressure conditions over the United States proper and Canada were much the same as prevailed over Alaska, with the lowest pressures over the northern districts, the usual summer condition. Exception should be noted, however, in the Atlantic States which were under the influence of the three tropical disturbances of the month, with the result that there was a quite uniform series of high and low pressure areas that also extended over northeastern Canada.

Over the Atlantic Ocean pressure was very nearly normal during the first week of the month, and this condition persisted throughout the month over the South Atlantic, except between the 13th and the 17th, when there was a considerable fall due to a tropical disturbance described below. To the northward, however, pressure was generally and substantially above the normal after the first week, except from the 21st to the 24th, inclusive, over the eastern ocean.

The persistence of the high pressure over the central western Atlantic Ocean, with the low pressure over Canada and the northern portion of the United States, resulted in a prolonged period of abnormally high temperature over the central and northern districts east of the Rocky Mountains that did not moderate until the last day of the month.

WASHINGTON DISTRICT.

The middle Gulf coast storm of July 1-10, 1916.

The first definite indications of this disturbance were noted on the morning of July 1 at Swan Island (latitude 17° N., longitude 84° W.), when after a day or two of unsettled weather the barometer had fallen to 29.78 inches with a 24-hour fall since the morning of the 30th of 0.06 inch. The air was calm, but about 1° to the northward an east wind of about 24 miles an hour prevailed with the same pressure as at Swan Island. Belated evening radio reports from vessels in the vicinity of Swan Island confirmed the morning indications, and on the morning of the 2d it was clearly evident that the disturbance was well defined with a northward movement. At this time the barometer at Swan Island read 29.74

inches, with fresh southerly winds and rain. Advisory warnings were then telegraphed to Weather Bureau stations along the Atlantic and Gulf coasts and to other interested parties. On the morning of the 3d the storm center was estimated to be at about latitude 20° N., longitude 85° W., but the absence of radio reports prevented more precise location. The barometer at Swan Island had risen 0.02 inch to 29.76 inches, with fresh south winds still blowing. Pressure had also fallen materially over western Cuba; Pinar del Rio reported 29.82 inches, a fall of 0.08 in 24 hours, with moderate easterly winds and rain. Thus far the storm was apparently of not much intensity and notices to this effect were issued. No information was received during the remainder of July 3 until late at night when a single radio report at about latitude 23° N., longitude 86° W., showed a barometer of 29.50 inches with an east wind of 64 miles an hour.

On the morning of the 4th no radio reports were received except one from a point about 125 miles northwest of Habana. This gave a barometer reading of 29.72 inches, with a southeast wind of 40 miles an hour. A report from Key West received at 10:21 p. m., July 4 stated that the United States Coast Guard cutter *Itasca* had encountered a severe disturbance on the afternoon of July 3 about 25 miles south of Cape San Antonio with a whole gale from the east. It was afterwards learned that the U. S. S. *Monterey* also came within the storm field during the 3d. At noon of that day in latitude 22° 31' N., longitude 86° 52' W., the barometer read 29.66 inches with a fresh breeze from the northeast. At midnight in latitude 22° 43' N., longitude 85° 58' W., the barometer read 29.42 inches with a strong gale from the east-northeast. The lowest barometer, 29.40 inches, was recorded at 2 a. m. on July 4 when a whole gale was blowing from the southeast, indicating that the storm center had passed but a short distance to the westward. These reports show that the storm passed through the Yucatan Channel during the early night of the 3d and apparently had attained only moderate intensity until just before that channel was reached, after which there was a marked increase in its activity. The effects were felt as far east as Habana, as indicated by the following cablegram from the director of the Cuban Meteorological Service:

[HABANA, July 4, 1916.]

4:30 p. m. Tropical storm reaching moderate intensity passed Yucatan Canal this morning moving northwest to central Gulf. Highest gusts in Habana 56 miles (at) noon. (Signed) GANGORI.

At Key West, Fla., the highest wind velocity was 36 miles south. At 9:50 p. m. of the 4th advices were issued to the effect that the storm had passed through the Yucatan Channel and caution was advised for all vessels in the Gulf of Mexico. Apparently the advices of the previous day had been carefully heeded for not a single radio report was received from the Gulf of Mexico from the evening of July 3 until after the storm center had passed inland to southern Mississippi. At 2 p. m. of the 4th after the receipt of noon special observations the following warning was issued:

Noon: Disturbance in southeastern Gulf of Mexico, but no reports to indicate intensity or exact direction of movement. Probably moving northwest toward central Gulf, and Gulf shipping advised to remain in port until further advices this evening.

At 8 p. m., with falling pressure along the Gulf coast, northeast storm warnings were ordered along the Gulf coast from the Louisiana coast to Pensacola, Fla., and cautionary advices sent elsewhere. The warning stated that the storm was then probably near the middle Gulf, moving northwestward and, if so, northerly winds and gales were probable Wednesday (July 5). The caution of the afternoon to shipping to remain in port was repeated. On the morning of the 5th the barometer on the middle Gulf coast ranged from 29.56 to 29.60 inches, with northeast winds that at Pensacola had reached a velocity of 48 miles an hour, indicating that the storm center had moved across the Gulf with unusual rapidity and was near to and approaching the middle Gulf coast, and apparently somewhere between Mobile Bay and the mouth of the Mississippi River. Hurricane warnings were therefore ordered

ing of the 6th the storm hovered over Mississippi and Alabama for three days with steadily decreasing intensity, but with torrential rains that caused great floods in the rivers of the East Gulf States and enormous damage to growing crops. By the morning of the 10th the storm center in its vagaries had moved into Tennessee (Nashville, 29.70 inches) and by the evening of the 10th was over extreme eastern Tennessee (Chattanooga, 29.80 inches). The damage done by the storm was of the character incident to such occurrences. Unfortunately sev-

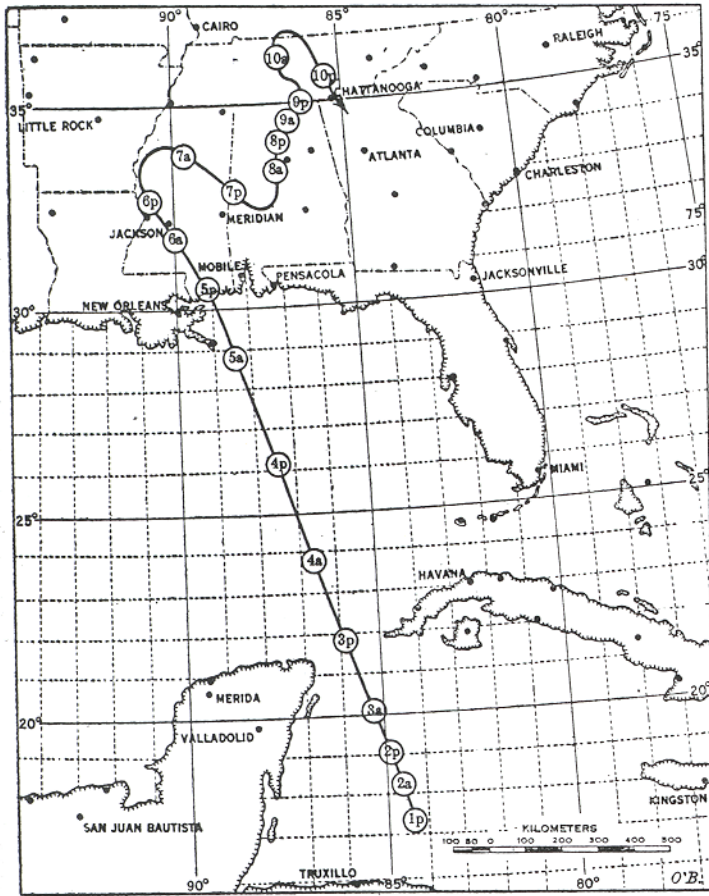


FIG. 1.—Track of the Middle Gulf storm of July 1-10, 1916.

at 9 a. m., from Mobile westward over the Louisiana coast and northeast storm warnings extended eastward to Carrabelle, Fla. Frequent special observations were obtained during the 5th but no changes in the warnings appeared to be necessary. The storm passed inland during the afternoon with a barometer reading of 28.92 inches at Mobile at 4:45 p. m. The maximum wind velocity was about 106 miles an hour, the highest velocity ever reported at that station. At Pensacola the lowest barometer reading was 29.31 inches at 2:30 p. m. and the maximum wind velocity was 104 miles an hour from the southeast at 2:32 p. m., also the highest velocity ever reported at that station. At 8 p. m. the barometer at Mobile read 29.05 inches. On the morning of the 6th the storm was central over southern Mississippi with a barometer reading at Meridian of 29.48 inches at 5 a. m. After the morn-

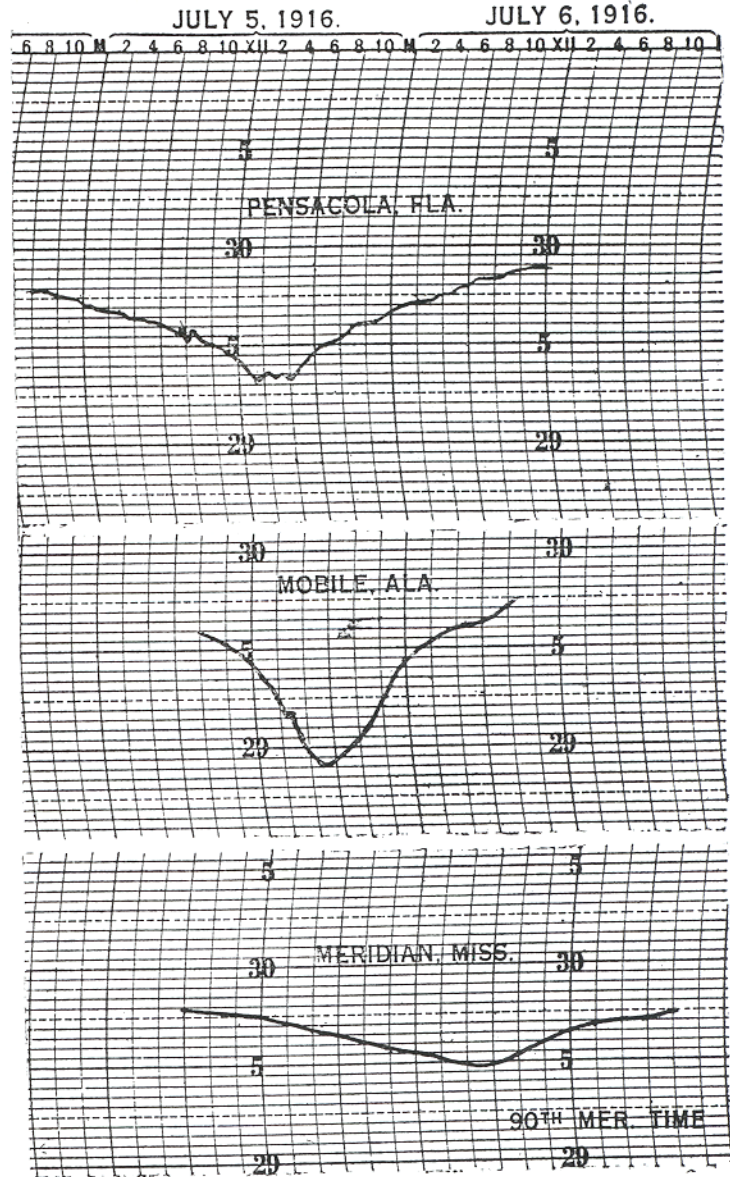


FIG. 2.—Barograms for a portion of the Middle Gulf storm of July 1-10, 1916, at Pensacola, Fla., Meridian, Miss., and Mobile, Ala. (sea-level records).

eral lives were lost along the middle Gulf coast, mainly persons in small boats. Marine casualties were of a minor character but the aggregate losses amounted to several millions of dollars, distributed principally between the cities of Pensacola and Mobile and the agricultural sections of southeastern Mississippi and southwestern Alabama. The high tides were responsible for the major portion of the coast damage. At Mobile the tide was somewhat more than 2 feet above the previous highest tide of 9.87 feet above mean tide in September, 1906, and the entire business district was inundated. At Pensacola

the tide was 5 feet above normal high tide, or 3½ feet lower than the highest reached during the storm of September, 1906. After the storm center passed inland torrential rains set in over the east Gulf States, and western Georgia and continued in the form of heavy showers for about a week. These rains of course caused enormous losses of staple crops and caused great floods in the rivers of eastern Mississippi, Alabama, and western Georgia.

Figure 1 shows the path of the hurricane and figure 2 copies of barograms recorded at Pensacola, Mobile, and Meridian:

On the morning of the 9th, when the hurricane storm was central over Alabama with some indications of redevelopment and northeastward movement, southwest storm warnings were ordered on the south Atlantic coast from Jacksonville, Fla., to Morehead City, N. C. The warning was hardly justified at the time, but, as it was Sunday, the receipt of special reports in time was doubtful and it was thought best to exercise due caution. The highest wind velocity reported during the display was a thunderstorm squall of 48 miles an hour at Jacksonville, while only fresh winds occurred to the northward.

The south Atlantic coast storm of July 12-15.

On July 12 a vessel radio report from about latitude 27° N., longitude 72° 30' W., gave the first notice of this disturbance. The wind was blowing 28 miles an hour from the west, and the barometer read 29.90 inches, an apparent fall. There was no other barometer reading below 30.00 inches in that locality. Pressure was high (30.30 inches) over Bermuda and moderately high (30.14 to 30.16 inches) on the Carolina coast. On the following morning another single radio report from about latitude 27° N., longitude 80° W., showed a barometer of 29.77 inches, with a strong westerly gale, indicating a storm of considerable intensity a short distance to the northeastward. Eleven a. m. special observations from coast stations showed little barometric change, but other conditions were threatening and at 12:30 p. m. northeast storm warnings were hoisted from Tybee Island, Ga., to Morehead City, N. C., and at 3:30 p. m. were extended northward to Coinjock, N. C. Northwest warnings were also displayed at Jacksonville. Late afternoon special reports indicated that the storm center was approaching the coast and at 7 p. m. hurricane warnings were ordered from Tybee Island, Ga., to Georgetown, S. C. By 8 p. m. the barometer at Charleston read 29.62 inches, and the highest wind had been 64 miles an hour from the northeast, with a very high tide. Savannah reported a maximum wind velocity of 38 miles an hour from the northeast, while at Frying Pan Shoals, N. C., 40 miles an hour from the east was reported. This storm center passed inland over or very near Charleston about 4 a. m. of the 14th, with a lowest barometer reading of 29.02 inches. At 8 a. m. the barometer read 29.40 inches and the wind had decreased to 42 miles from the southwest.

As pressure was falling to the north at 8 p. m. July 13, northeast storm warnings were ordered at 10 p. m. from Hatteras, N. C., to Fort Monroe, Va., but as the storm center kept on inland, nothing more than fresh winds occurred, and the warnings were lowered at 9 o'clock on the following morning. At 8 p. m. of the 14th the storm center was over central South Carolina, with a barometer reading of 29.58 inches and with a maximum wind velocity at Columbia of 36 miles an hour from the northeast. At the same observation, Charlotte, N. C., reported a maximum wind velocity of 52 miles from the

east, and another of 56 miles an hour from the east during the night. On the morning of the 15th the remnants of the storm were lost in the mountains of western North Carolina. Strong winds and moderate gales continued at Charleston, S. C., until the night of the 14th-15th.

This is the history of this disturbance so far as it is possible to give it from the Weather Bureau reports available at the time. On July 22 there were received by mail a series of observations from the U. S. S. *Hector*, which was wrecked by the storm, and some notes from the log of the U. S. S. *Terry*, which was also in the vicinity of the storm. It is greatly to be regretted that it was not possible to receive radio reports from these vessels on July 11 and 12, as only two reports were received from merchant vessels, one each on July 12 and 13, both south of latitude 28° N. The observational data from the *Hector* and the notes from the *Terry* follow.

TABLE 1.—Meteorological observations taken on board U. S. S. *Hector* during July 12 to 14, 1916.

Date.	Hour.	Ship's position.		Wind.		Barometer. ¹	Thermometer.	Weather. ²
		Latitude N.	Longitude W.	Direction.	Force.			
1916.								
July 12.....	P. M.					Inches.	° F.	
	4:00	32 38	79 42	n. by e.	4	30.02	84	bc
	6:00	32 21	79 30	e. by n.	3	29.99	84	bc
	8:00	32 07	79 21	e. by n.	5	29.99	84	bc
	10:00	31 55	79 13	e.	5	29.96	84	bcq
	12:00	31 46	79 07	e.	5	29.88	82	bcqg
	A. M.							
	2:00	31 37	79 02	ese.	7	29.80	80	ocr
	4:00	31 35	79 01	ese.	8	29.70	82	ocr
	6:00	31 34	79 00	ese.	8	29.61	80	ocr
	8:00	31 34	79 00	e. by n.	10	29.48	79	ocqr
	10:00	31 38	78 58	ne.	12	29.20	77	ocqr
Noon.	31 41	78 56	ne.	12	28.72	79	ocqr	
13.....	P. M.							
	2:00	31 43	78 55	ne.	12	28.60	78	ocqr
	3:30	31 45	78 53	e. by n.	12	28.30	77	ocqr
	4:00	31 46	78 53	e. by n.	12	28.40	77	ocqr
	6:00	31 48	78 52	e.	12	28.50	77	ocqr
	8:00	31 51	78 50	e.	12	28.60	78	ocqr
	10:00	31 54	78 49	se.	12	28.75	78	ocqr
	12:00	32 03	78 48	s.	12	29.02	78	ocqr
	A. M.							
	2:00	32 11	78 55	s.	10	29.10	79	ocqr
	4:00	32 16	79 01	ssw.	10	29.30	79	ocqr
	6:00	32 22	79 09	sw.	9	29.40	80	ocq
8:00	32 31	79 08	sw.	9	29.66	80	ocq	
10:00	32 40	79 07	sw.	8	29.70	80	ocq	
Noon.	32 50	79 06	sw.	7	29.74	80	oc	
14.....								
2:00	32 11	78 55	s.	10	29.10	79	ocqr	
4:00	32 16	79 01	ssw.	10	29.30	79	ocqr	
6:00	32 22	79 09	sw.	9	29.40	80	ocq	
8:00	32 31	79 08	sw.	9	29.66	80	ocq	
10:00	32 40	79 07	sw.	8	29.70	80	ocq	
Noon.	32 50	79 06	sw.	7	29.74	80	oc	

¹ Aneroid barometer reads 0.07 inch too low.

² b, clear blue sky; c, cloudy weather; q, squally weather; o, overcast; r, rainy weather or continuous rain; g, gloomy or dark.

Log of the Terry.—The following data were taken from the log of the *Terry*; barometer readings were taken by an aneroid and are probably a little too high; error unknown.

July 11, 8 p. m.: Position, latitude 26° 06', longitude 79° 35'. Calm; long rolling sea from the eastward; barometer steady, 30.19.

July 12, noon: Position, latitude 29° 01', longitude 79° 33'. Commenced to breeze up in the afternoon, wind increasing to force 8. Barometer dropped from 30.12 at noon to 30.01 at midnight; wind northeast, wind waves making up; heavy cross sea from the eastward.

July 13, noon: Position, 50 miles south of Charleston Lightship. A. m., wind increased to force 10, north by east to north-northeast. Barometer dropped to 29.85.

P. m., wind north-northeast., increased to force 12.

7 p. m., wind north, force 12, barometer 29.66.

9 p. m., wind northwest, force 12, barometer 29.58.

Midnight wind, northwest, force 12, barometer 29.51.

July 14, 1 a. m.: wind west, force 10, barometer 29.50.

2 a. m., wind west, force 10, barometer 29.49. Position, 10 miles east of Hunting Island Light.

4 a. m., wind northwest, force 6, barometer 29.44.

6 a. m., wind southwest, force 10, barometer 29.45. Position, 6 miles south of Charleston Lightship.

July 14, 8 a. m., wind southwest, force 11, barometer 29.61.
 10 a. m., wind south-southwest, force 10, barometer 29.64.
 12 noon, wind south-southwest, force 9, barometer 29.85.
 2 p. m., wind southwest, force 5, barometer 29.89.
 4 p. m., wind south, force 5, barometer 29.88.
 6 p. m., wind south by east, force 7, barometer 29.95.
 8 p. m., wind south by east, force 7, barometer 29.99.
 10 p. m., wind southeast, force 10, barometer 30.03.
 12 midnight, wind south, force 8, barometer 30.07.
 July 15, 2 a. m.: wind south-southeast, force 5, barometer 30.11.
 4 a. m., wind south by east, force 5, barometer 30.12.
 6 a. m., wind south, force 5, barometer 30.15.
 8 a. m., wind south, force 5, barometer 30.17.

The tropical storm of July 12-22, 1916.

The first indication of this disturbance was a marked fall in pressure over the Windward Islands during the 24 hours ending at 8 a. m. of July 12. Light southeast winds were blowing from St. Kitts to Port of Spain, with an average pressure of 29.90 inches, while at San Juan, P. R., the barometer read 29.96 inches with a fresh northeast wind. During the five succeeding days this storm center moved slowly northwestward and apparently was of but moderate intensity; on the morning of the 17th it was central at approximately latitude 23° N., longitude 73° W., with a northward tendency. Advisory warnings regarding the storm were first issued on the morning of July 12 and one or more each day thereafter until the evening of the 18th, when the storm center was about at latitude 30° N., longitude 74° W., with a northward movement. Northeast storm warnings were then ordered from Wilmington, N. C., to Delaware Breakwater, and on the following morning were extended to Boston, the storm center being then at about latitude 33° N., longitude 74° W. Radio messages from vessels had shown strong gales, and during the 19th moderate gales occurred on the North Carolina coast and at the Virginia Capes. On the evening of the 19th the northeast storm warnings were continued from Hatteras, N. C., to Delaware Breakwater (except at Baltimore), and on the morning of the 20th northward to Boston, at which time the storm was apparently central at latitude 37° N., longitude 74° W., with a tendency toward a slight recurve to the northeastward. No radio reports were received from that vicinity during the 20th, but strong northerly winds prevailed along the coast as far as New York. On the morning of the 21st the storm was central south of and very near the New England coast; the barometer reading this day of 29.38 inches at Block Island, R. I., was the lowest reported reading during the storm. Moderate easterly gales had extended as far north as Nantucket, Mass., and northeast warnings were ordered at all display points north of Boston. At the same time the warnings south of Boston were changed to northwest. The storm continued northeastward with diminishing intensity and without strong winds north of Massachusetts. By the morning of the 22d this storm had passed into Newfoundland.

Neither storm nor small-craft warnings were displayed during the month on the Great Lakes.

DISTRICT WARNINGS DURING JULY.

Chicago District.—No frost warnings were issued or required during the month. Fire-weather warnings were issued for South Dakota and Wyoming on the 3d.—*Chas. L. Mitchell, Assistant Forecaster.*

Denver District.—No special warnings were issued during the month.—*Frederick H. Brandenburg, District Forecaster.*

New Orleans District.—The hurricane of July 5, the western segment of which passed over southeastern Louisiana, was the only storm that occurred in this district during the month. Warnings of this hurricane were timely and the effective distribution of the same prevented the loss of property and probably loss of life. Small-craft warnings were ordered for the Texas coast on the 30th, on account of unsettled conditions in that region. All warnings were justified and no storm occurred without warnings.—*I. M. Cline, District Forecaster.*

Portland, Oreg., District.—In this district July is normally a pleasant month, but this year the portion of the North Pacific seasonal high-pressure area, touching and at times overlapping the North Pacific coast, was generally so far south that a southerly gradient obtained and local showers in western Oregon and particularly Washington were of frequent occurrence. The total monthly precipitation recorded at Portland exceeded the previous July record by 0.29 inch. Local showers fell east of the Cascade Mountains during the first week and near the middle of the month.

Only one special warning was issued during the month, giving information to alfalfa interests. This was sent out on the morning of the 11th and stated:

Favorable weather alfalfa harvest, indicated Wednesday, Thursday, and probably Friday.

This warning might well have been issued a day earlier, but the probable southeastward movement of the moderate disturbance that was central near Sitka on the afternoon of the 9th gave indication of coming unsettled weather conditions, and this was apparently confirmed by the decreasing pressure noted on the morning of the 10th along the North Pacific coast. The warning was, therefore issued at a time when the pressure was decreasing and an aneroid barometer in the hands of farmers might cause some apprehension as to probable coming weather conditions. Normal July weather in the alfalfa districts is favorable for harvesting operations, hence information of expected stormy periods, or of favorable weather when local signs seem to indicate a change, is of real value to the alfalfa grower. Although in this instance thundershowers occurred on the night of the 12th (Wednesday) in extreme eastern Washington and adjoining portions of Idaho, the amounts of precipitation falling in alfalfa sections were slight and no reported damage resulted. The warning was therefore a success.—*T. Francis Drake, Local Forecaster.*

San Francisco District.—No important warnings were issued in this district during the month.

The Forest Service was warned of warmer weather with drying northerly winds and conditions favorable for forest fires on the 10th, 11th, and from the 17th to the 23d. Subsequent conditions showed that the warnings were timely.—*G. H. Willson, District Forecaster.*

A special chart, showing hurricane tracks for the season of 1916 will appear in the December issue of the Review.

SAN JUAN, P. R., July 28, 1916.

To the CHIEF, U. S. Weather Bureau,
Washington, D. C., U. S. A.

SIR: Sailed at 10:15 a. m., July 16, 1916, from Norfolk, Va., bound for Porto Rico to load bunker coal.

Met at first fresh southeasterly breezes with cloudy sky (the greater part cumulus). At 8 p. m. the wind became more southerly and during the watch from midnight till 4 a. m. it was calm with clear sky. In the forenoon of the 17th the wind became more southerly, with a force of 2 (Beaufort scale). It now became cloudy (cumulus and cumulo-nimbus). The barometer was observed continually, as we had read in the newspapers about a hurricane that had passed Porto Rico on July 12.

The average barometric pressure was 30.04 inches, and the temperatures were not out of the ordinary.

In the afternoon of the 17th the wind increased and shifted after 4 p. m. to east-southeast, increasing until a force of 6 was reached, while the sea became more turbulent. The barometer fell a little to 29.92 inches. The daily amplitude was normal. During the watch from midnight till 4 a. m. of the 18th the wind shifted to northeast, increasing to a force of 7, the barometer fell to 29.90 inches, the sea became more turbulent. A swell started from south-southeast with passing showers. After 4 a. m. it started to rain, while the wind increased after 8 a. m. to a force of 8 and 9. The barometer at 8 a. m. read 29.86 inches, and the wind shifted to north-northeast. The barometer fell to 29.76 inches at 11 a. m. and to 29.72 at noon, and the sea was very high with overcast sky. In the afternoon the wind shifted to east-northeast, increasing to a force of 10, with heavy rainfall, dirty sky, and a very high and turbulent sea. At 1 p. m. the barometer read 29.65 inches, at 2 p. m. 29.61 inches, and at 4 p. m. 29.53 inches. During the watch from 4 p. m. to 8 p. m. the wind became more easterly, and at 8 p. m. the barometer read 29.49 inches. After 8 p. m. the wind became more east-southeasterly with a force of 10: very high and turbulent sea, heavy rain squalls with hard sky. The barometer at midnight read 29.28 inches. After this the wind increased to a force of 11 and 12, while the barometer was falling rapidly. The wind continued east-southeasterly until the ship was in the center of the hurricane, when the barometer read 28.94 inches. Heavy rain squalls. Here the seas came from all directions. About 2 a. m. of the 19th the wind went down to force 5 and hauled to southwest through south, increasing from 3 a. m.; the rain stopped and the sky cleared a little. During the heaviest wind there was a high, regular sea from east-southeast; nearing the center it became irregular, but all the time, and throughout the entire storm field, we experienced a high swell from south-southeast. After 4 a. m. the wind became more southwesterly and decreased a little. Very heavy rain squalls with phenomenal sea and overcast sky. The barometer rose, and at 8 a. m. read 29.41 inches. During the whole day the wind blew principally from southwest with a force of 9. The barometer rose continually and at 11 a. m. read 29.57 inches, at noon 29.61 inches, at 4 p. m. 29.68 inches, at 8 p. m. 29.78 inches, and at midnight 29.82 inches. There was a very high and irregular sea with high swell, and further very heavy rain squalls with overcast sky. On the following day (20th) the barometer rose steadily, the wind decreased and became more westerly, and on the morning of the 21st shifted gradually to the east, after which the usual trade wind was met. During July 20 there were still heavy rain squalls with more or less covered sky and southwest and northeast swells. When the sky cleared in the afternoon of the 20th cirrus appeared with the radiation point bearing northwest, on the morning of the 21st north, and during the remainder of the day and also on the 22d north-northeast and northeast, the sky becoming free of cirrus during the afternoon of the 22d.

Barometer readings on July 20 were as follows: 4 a. m. 29.95 inches, 5 a. m. 29.96 inches, 8 a. m. 30.04 inches, noon 30.08 inches, 4 p. m. 30.08 inches, 8 p. m. 30.12 inches, midnight 30.16 inches.

Owing to the high sea and swell it was impossible to make any speed, and we met the hurricane at about 32° 30' north latitude and 73° west longitude.

FURTHER DATA ON THE TROPICAL STORM OF JULY 12-22, 1916.

By Prof. H. C. FRANKENFIELD.

[Dated: Weather Bureau, Washington, Oct. 13, 1916.]

The following report sheds some additional light on the behavior of the tropical storm of July 12-22, 1916, a brief account of which was published in the MONTHLY WEATHER REVIEW for that month. The report was prepared by Mr. T. Edelenborsch, second officer of the steamship *Ausable*, who made the observations, and is published in the MONTHLY WEATHER REVIEW in order that the record may be made as complete as possible.

The report has been edited slightly, and the millimetric barometer readings converted into inches:

HURRICANE OF JULY 5, 1916, AT PENSACOLA, FLA.

By WILLIAM F. REED, Jr., Local Forecaster.

[Abstracted for the MONTHLY WEATHER REVIEW.]

The first information at Pensacola concerning the tropical disturbance of July 5 came at 10:43 a. m., Sunday, July 2, when it was reported near Swan Island in latitude 17° N., longitude 84° W. At 9:33 p. m., July 3, an advisory message was received giving its location as latitude 20° N., longitude 85° W. and moving north or northwest. On the morning of the 4th an advisory message stated that the late reports of the 3d indicated that the disturbance had passed through the Yucatan Channel, and warning cards were sent to all shipping interests and posted by messenger. All advices concerning the development and progress of the storm were published in the newspapers and on the daily weather maps. An advisory message received at 2:15 p. m. on the 4th stated that at noon the disturbance was in the southeast Gulf of Mexico, but there were no reports to indicate its intensity or exact direction of movement, and shipping was advised to remain in port until further advices. At 9:03 p. m. on the 4th an order was received to hoist northeast storm warnings from Bay St. Louis to Pensacola, with information that no information was available as to the location of the Gulf storm, but its center was probably near the middle Gulf moving northwest and caution was repeated for vessels to remain in port.

A gentle to moderate southeast breeze on the afternoon of the 4th decreased to light winds between 5 to 7 p. m., then a moderate northeast breeze set in, increasing to fresh by 12 p. m. A moderate surf along the Gulf beach in the afternoon, as if from local conditions, fell off with the wind but at night it became high and alarming, and the few people who were at the bathing pavillions on Santa Rosa Island sought refuge at the Coast Guard Station.

On the morning of the 5th all were aware that the hurricane was nearing the coast and every precaution was taken to protect life and property. The flagstaff on the roof of the American National Bank Building broke off at a splice in the pole and fell to the ground with the storm flags about 5:45 a. m. during a 40-mile gale. About 7:30 a. m. a rescue tug was called for to go to Santa Rosa Island, as the Coast Guard Cutter *Penrose* could not weather the increasing storm. Capt. Aiken of the Aiken Tow Boat Co., said he would send a tug by the island while moving some fishing smacks across the bay, which would be without cost; the tug *Simpson* was sent across, but could not make a landing. She was nearly swamped in the bay and sought shelter at quarantine station and the bluffs on the peninsula, returning to Pensacola on the 6th.

The tide at 8 a. m. was 3 feet above normal high water; at 9:30 a. m., 3½ feet and steadily rose to 5 feet by 2 p. m., remaining at 5 feet until 6:30 p. m. when it began to fall. About 2 p. m. the tide flooded the engine room of the Pensacola Electric Co.'s Power Plant, shutting off all light and power current.

A steady rain set in at 3.05 a. m. on the 5th and continued all day, shutting off the view; objects about 3 miles away could be seen when the rains were lightest.

The regular 7 a. m. observation on the 5th gave the pressure 29.57 inches, wind northeast, 48 miles, and nimbus clouds from the east; a special observation at 8 a. m. reported a pressure of 29.58, wind 72 miles from the east-

southeast, and nimbus clouds east-southeast, high surf and tide 3 feet above normal. An observation at 10 a. m. reported pressure 29.51, wind 75 miles southeast, maximum wind 79 miles from the east, and nimbus clouds from the southeast. The 10 a. m. message was the last one that could be sent as wires were falling and the radio station was disabled. In taking readings for special observations from roof apparatus at 8 a. m., 10 a. m., and 3 p. m., a rope was tied to the observer, W. F. Reed, jr.; no attempt was made to get to the instrument shelter or raingage at 1 p. m. when a 92-mile gale with severe puffs from the southeast was blowing, so the office registers were consulted for the temperature and precipitation items usually obtained from the roof.

When the wind passed the 80-mile rate people could not stand at the cross streets, and when they attempted to cross were thrown down and had to creep if they could not hold on to something. Automobiles could not make headway against the wind and had to seek shelter or be blown around at the mercy of the wind; a few were turned over.

The special readings of the mercurial barometer (Table 1) were taken by W. F. Reed, jr., local forecaster, and Gerald S. Kennedy, assistant observer, in the Weather Bureau office on the 10th floor of the American National Bank Building. There was considerable vibration in the building during the storm and pumping of the barometers necessitated averaging the settings of the vernier. This vibration, combined with the moist air which was carried and driven into everything by the high winds, caused broadening of lines on the registering instruments, especially the barograph and thermograph.

A copy of the barograph trace sheet for the 5th, 6th, and 7th is shown in figure 2 on p. 397.

The duration of the gales was extraordinary owing to the slow northerly progress of the storm after it reached the Mississippi coast; and when it curved eastward from central Mississippi on the morning of the 7th moving slowly into northern Alabama by the night of the 8th, it caused south to southwest gales of 40 miles or over at Pensacola from 9 a. m. the 7th to 2 p. m. on the 8th. A tabulation of the winds and rainfall on July 5, 6, 7, and 8 is given herewith.

TABLE 1.—Special barometer readings at Pensacola, Fla. (reduced to sea-level).

[By W. F. Reed, jr., and G. S. Kennedy.]

Hour (90th M.).	June 5, 1916.	June 6, 1916.
A. M.		
7:00.....	Inches. 29.57	Inches. 29.84
8:00.....	29.58	.....
9:00.....	29.54	.....
9:30.....	29.52	.....
10:00.....	29.51	29.89
10:30.....	29.48	.....
11:00.....	29.46	29.90
NOON.....	29.43	29.90
P. M.		
12:30.....	29.40	.....
1:00.....	29.37	.....
1:30.....	29.31	.....
2:00.....	29.37	.....
2:30.....	29.37	.....
3:00.....	29.36	.....
4:00.....	29.35	.....
5:00.....	29.40	.....
5:30.....	29.44	.....
6:00.....	29.47	.....
7:00.....	29.51	.....
8:00.....	29.54	.....

TABLE 2.—Hourly observations at Pensacola, Fla., July 5-8, inclusive, 1916.

Time. (90th meridian).	July 5, 1916.						July 6, 1916.						July 7, 1916.						July 8, 1916.								
	Wind.						Wind.						Wind.						Wind.								
	Prevailing direc- tion.	Hourly move- ment.	Maximum.			Hourly rainfall.	Prevailing direc- tion.	Hourly move- ment.	Maximum.			Hourly rainfall.	Prevailing direc- tion.	Hourly move- ment.	Maximum.			Hourly rainfall.	Prevailing direc- tion.	Hourly move- ment.	Maximum.			Hourly rainfall.			
			Velocity.	Direction.	Time.				Velocity.	Direction.	Time.				Velocity.	Direction.	Time.				Velocity.	Direction.	Time.				
	Mis.	Mis./hr.			In.	Mis.	Mis./hr.			In.	Mis.	Mis./hr.			In.	Mis.	Mis./hr.			In.	Mis.	Mis./hr.			In.		
A. M.																											
12-1	ne.	25			T.	s.	58	67	s.	12:03	0.01	s.	32			0	sw.	39	50	sw.	12:19	T.					
1-2	e.	28				s.	59	61	s.	1:17	0.01	s.	32			0	sw.	37	42	sw.	1:19		0.30				
2-3	e.	33				s.	55	60	s.	2:26	0.04	s.	34			0	sw.	31	45	sw.	2:52		0.10				
3-4	e.	39	46	e.	3:17	T.	s.	56	60	s.	3:13	0.03	s.	35			0	sw.	40	46	sw.	3:32		0.24			
4-5	e.	37	40	e.	4:53	0.05	s.	54	56	s.	4:28	0.01	s.	37			0	sw.	38	49	sw.	4:05		0.10			
5-6	ne.	42	46	e.	5:45	0.10	s.	52	58	s.	5:10	T.	s.	36			0	sw.	40	46	sw.	5:54		0.20			
6-7	e.	45	48	ne.	6:52	0.02	s.	51	55	s.	6:04	T.	s.	34			0	sw.	40	49	sw.	6:08		0.06			
7-8	ne.	46	48	e.	7:56	0.35	s.	49	52	s.	7:19	T.	s.	35			0	sw.	41	49	sw.	7:34		0.03			
8-9	e.	49	64	e.	8:45	0.34	s.	50	53	s.	8:43	0.03	s.	38			0	sw.	42	48	sw.	8:02		0.01			
9-10	e.	67	79	e.	9:53	0.05	s.	48	50	s.	9:34	T.	s.	41	44	s.	9:17	T.	sw.	31	50	sw.	9:08		1.27		
10-11	e.	77	84	e.	10:42	0.10	s.	46	48	s.	10:02	0	s.	40	43	s.	10:06	0.01	sw.	41	44	sw.	10:33		0		
11-12	se.	83	90	se.	11:35	0.29	s.	43	48	s.	11:13	0	s.	38	40	s.	11:03	T.	sw.	38	42	sw.	11:35		0		
P. M.																											
12-1	se.	91	96	se.	12:48	0.13	s.	41	44	s.	12:32	T.	s.	38	42	s.	12:46	0.01	sw.	38	42	sw.	12:55		0		
1-2	se.	92	104	se.	1:29	0.50	s.	37	43	s.	1:02	0.01	s.	41	44	sw.	1:27	T.	sw.	34	40	sw.	1:12		0		
2-3	se.	79	84	se.	2:02	0.27	s.	36	40	s.	2:39	0	s.	44	44	sw.	2:13	T.	sw.	34					0		
3-4	se.	81	86	se.	3:07	0.08	s.	34				0	s.	45	46	s.	3:42	T.	sw.	38					0		
4-5	se.	80	85	se.	4:32	0.08	s.	32				0	s.	44	46	s.	4:10	0	sw.	36					0		
5-6	s.	78	84	s.	5:30	0.02	s.	30				0	sw.	42	44	s.	5:05	0	sw.	35					0		
6-7	s.	68	73	s.	6:06	0.04	s.	28				0	sw.	41	42	sw.	6:22	0	w.	26					0.11		
7-8	s.	66	72	s.	7:27	0.02	s.	30				0	sw.	41	42	sw.	7:29	0	w.	20					1.46		
8-9	s.	62	68	s.	8:22	T.	s.	31				0	sw.	47	52	sw.	8:49	0.05	sw.	15					0		
9-10	s.	63	68	s.	9:40	0.08	s.	33				T.	sw.	26	44	sw.	9:55	0.27	sw.	18					0.03		
10-11	s.	69	74	s.	10:33	0.01	s.	31				0	sw.	44	47	sw.	10:42	0.04	w.	14					0		
11-12	s.	72	80	s.	11:10	0.02	s.	34	40	s.	11:05	0	sw.	48	50	sw.	11:40	T.	w.	12					0		
Total.....		1,472			2.55		1,018			0.14		933					0.38		778							3.91	
Mean.....		61.3					42.4					38.9							32.4								
Extreme velocity.....			110 se.		at 1:32 p. m.					76 s.							at 8:58 p. m.									54 sw.	at 12:21 a. m.
Highest temperature.....					81° F.					81° F.							80° F.										80° F.
Lowest temperature.....					74° F.					76° F.							73° F.										71° F.

Average hourly wind velocity 6 a. m. 5th to 6 a. m. 6th, 66.8 miles.
 Average hourly wind velocity 6 a. m. 5th to 12 noon 5th, 61.2 miles.
 Average hourly wind velocity 12 noon 5th to 6 p. m. 5th, 83.5 miles.
 Average hourly wind velocity 6 p. m. 5th to 12 midnight 5th, 66.7 miles.
 Average hourly wind velocity 12 midnight 5th to 6 a. m. 6th, 55.7 miles.

DAMAGE BY WIND.

One would think that the damage by wind during this storm would be much greater than the results observed and listed,¹ as compared with the storm of September 27, 1906, when the gales attained the rate of only 80 miles or over during 3 hours of record, the maximum rate for 5 minutes being 83 miles from the southeast. The fact remains, however, that back to the beginning of Weather Bureau's records at Pensacola, which was on October 27, 1879, there were no storms showing greater velocities than the 72 miles from the north on July 7, 1896, so that when the storm of September 27, 1906, came with its rate of 83 miles, the structures that were weakened by decay or not properly built, the old roofs and the old trees had to go, leaving little for the gales of 80 miles or over in this storm to do. It is thought, too, that the gales of this storm did not carry the characteristic severe puffiness of hurricane winds, but were comparatively steady.

The estimated damage by wind in Pensacola and vicinity and to ships' rigging is \$150,000, while that caused by tide and wave action in undermining, tearing down, shifting of sand and other materials, breaking up of wharves, and shifting and breaking up of vessels, is \$850,000, making a total of \$1,000,000.

¹ Mr. Reed has listed the casualties in great detail. They are not given here on account of lack of space. No lives were lost, and no single casualty was of abnormal character.

The damage by wind and water was of the character incident to such storms, and was widely and quite evenly distributed. In the city and vicinity sheds, roofs, smokestacks, etc., were blown away, and many houses were unroofed. The damage to trees, shrubbery, and crops is difficult to estimate. Sycamore and china-berry trees suffered most, and a full line of trees on Chase Street, near the courthouse, was blown down. Trees are down and limbs broken off in all portions of the city many falling across the streets and obstructing traffic.

Seven hydroplane hangars blew down at the aeronautic station. They were made of canvas, but the engines and pontoons were removed to brick buildings and saved from damage.

Small craft and wreckage were strewn all along the water front from the harbor entrance to Escambia Bridge. Nearly all structures along the docks suffered more or less severely, and a great many vessels, mostly small ones, were wrecked or blown ashore. A detailed account of these casualties would be but a useless repetition.

High winds at Pensacola.—In connection with the popular queries arising from this recent storm Mr. William F. Reed, jr., compiled a table of previous high winds (velocities of 50 miles per hour or over, maintained for at least 5 minutes) recorded by Weather Bureau or Signal Service instruments at Pensacola, Fla. The compilation is here presented as Table 3.

TABLE 3.—Recorded occasions with winds attaining 50 miles per hour or over, at Pensacola, Fla., from Nov. 14, 1879, to July 20, 1916.

[Maximum velocities maintained for 5 minutes or more.]

Five-minute velocity.	Direction.	Date.	Five-minute velocity.	Direction.	Date.	Five-minute velocity.	Direction.	Date.
Ms./hr.			Ms./hr.			Ms./hr.		
50 n.		Sept. 9, 1882	54 se.		Feb. 21, 1910	76 se.		May 11, 1912
60 sw.		Aug. 20, 1888	54 e.		Feb. 26, 1910	59 se.		Sept. 13, 1912
50 sw.		Jan. 21, 1891	50 se.		Apr. 15, 1910	74 se.		Sept. 14, 1912
52 s.		Aug. 17, 1892	36 sw.		Apr. 24, 1910	50 s.		Oct. 18, 1912
50 sw.		Dec. 31, 1892	58 s.		Nov. 28, 1910	60 s.		Jan. 26, 1913
57 w.		Apr. 20, 1893	52 se.		Dec. 22, 1910	56 sw.		Feb. 27, 1913
66 sw.		Oct. 2, 1893	60 s.		Feb. 19, 1911	54 s.		Mar. 21, 1913
56 se.		Nov. 27, 1893	53 e.		Mar. 26, 1911	52 s.		Sept. 5, 1913
52 se.		Aug. 7, 1894	52 se.		Apr. 5, 1911	60 se.		Feb. 6, 1914
68 ne.		Oct. 8, 1894	52 nw.		Apr. 11, 1911	62 se.		Nov. 27, 1914
72 n.		July 7, 1896	68 e.		Apr. 26, 1911	60 se.		Nov. 28, 1914
54 se.		Mar. 23, 1901	66 e.		Apr. 27, 1911	52 s.		Feb. 5, 1915
70 sw.		Aug. 15, 1901	50 e.		June 3, 1911	54 nw.		June 25, 1915
60 sw.		Dec. 28, 1901	58 se.		Aug. 10, 1911	50 ne.		July 10, 1915
52 sw.		Feb. 27, 1902	80 se.		Aug. 11, 1911	60 se.		Sept. 29, 1915
50 sw.		Mar. 29, 1906	56 s.		Aug. 12, 1911	64 s.		Sept. 30, 1915
52 ne.		Sept. 26, 1906	56 nw.		Nov. 12, 1911	70 sw.		Dec. 28, 1915
83 e.		Sept. 27, 1906	60 e.		Dec. 19, 1911	51 s.		Mar. 25, 1916
50 s.		May 31, 1907	80 se.		Dec. 20, 1911	52 s.		Apr. 7, 1916
63 s.		Aug. 19, 1909	52 sw.		Jan. 8, 1912	66 s.		June 13, 1916
53 n.		Aug. 28, 1909	58 sw.		Feb. 21, 1912	104 se.		July 5, 1916
64 se.		Sept. 20, 1909	62 nw.		Mar. 11, 1912	67 s.		July 6, 1916
60 s.		Sept. 21, 1909	50 s.		Mar. 14, 1912	52 sw.		July 7, 1916
52 se.		Dec. 12, 1909	56 s.		Apr. 17, 1912	50 sw.		July 8, 1916
60 s.		Feb. 17, 1910						

HURRICANE OF JULY 5-6, 1916, AT MOBILE, ALA.

By ALBERT ASHENBERGER, Meteorologist.

[Dated: Weather Bureau Office, Mobile, Ala., July 28, 1916.]

The hurricane of July 5-6, 1916, was more destructive within the city limits of Mobile than any other storm in the recorded meteorological history of this section.

THE WARNINGS.

On Sunday July 2 a telegram was received from the Central Office as follows:

Tropical disturbance central short distance north of Swan Island, approximately latitude 17° north, longitude 84° west; apparently moving north or northwest.

The information was bulletined; and the warning was published in the Mobile Register on July 3. Subsequent warnings received were bulletined and given to the press; on July 4, the harbormaster and the pilots' office were informed that no vessels should leave port, and the Mobile Item published two of the warnings. The storm warning received at 9:13 p. m. July 4 was bulletined, repeated to the substations on the Alabama coast (except Fort Morgan, the telegraph office to which was closed), and published in the morning Mobile Register of July 5. The hurricane warning received at 9:53 a. m. July 5 was given extraordinary dissemination; and in the work the office had the cooperation of the Mobile & Ohio Railroad, the Louisville & Nashville Railroad, the Home Telephone Co., and the Southern Bell Telephone & Telegraph Co. At about 11 a. m. the chief of police was requested to notify parties along the river front that high tides were expected. The telegraph line to Fort Morgan was down from July 4, and the telephonic communication to points in Baldwin County, Ala., was interrupted before the warning could be sent out.

METEOROLOGICAL CONDITIONS.

No unusual cloud formations or optical phenomena were observed on the day preceding the storm. A thunderstorm occurred on the afternoon of July 4; light

rain began between 4 and 5 a. m. of July 5 and the gusty character of the wind was noticeable at about 4:30 a. m. of the 5th.

On July 4 there was a slight decrease in barometric pressure, but there were only gentle winds excepting a squall with a maximum velocity of 33 miles, from the east, which occurred at about 3 p. m., during the thunderstorm. The barometric pressure decreased steadily on July 5, the fall becoming more rapid until about 3.06 p. m. at which time the rapid fall ceased and the wind reached its highest velocity, a maximum of 107 miles an hour from the east. (See fig. 2, p. 397.) The barometer registered a minimum of 28.92 inches at 3:45 p. m. July 5 and began to rise rapidly after 6 p. m. Prior to the squall on July 4 the wind was prevailing from the southeast; subsequently it varied from east to north till about 9 p. m., after which it came constantly from the northeast till noon of July 5. In the afternoon it gradually veered to east, changed to southeast between 4 and 5 p. m., and was generally south after 11 p. m. The wind reached a velocity of 26 miles an hour at 4:55 a. m. July 5; and a maximum of 44 miles at 10:07 a. m. was the highest in the forenoon. The wind increased rapidly after noon, reaching 60 miles an hour at 12:15 p. m., after which higher velocities were registered at intervals until the highest was reached at 3:06 p. m. The hourly wind movement from 3 to 4 p. m. was 99 miles; from 4 to 5 p. m., 81 miles; from 5 to 6 p. m., 88 miles; from 6 to 7 p. m., 91 miles; from 7 to 8 p. m., 84 miles; and then there was a decrease. The record was lost from 9:55 p. m., July 5, to 6:35 a. m., July 6, owing to a broken wire. A maximum of 40 miles an hour on July 6 last occurred, beginning at 9:04 a. m.

The rain which began on the morning of the 5th continued to 1:59 p. m. of the 6th, but was interrupted from 11:45 a. m. to 12:55 p. m. of the 6th. The total was 8.56 inches. Heavy rains on July 7, which amounted to 4.99 inches, caused considerable damage in unroofed houses, and the obstructions near the river caused the water to cover the lower floors in buildings on Water Street.

THE TIDES.

The tide in Mobile River was observed to be below normal at about 5:30 a. m. July 5. The water began to rise rapidly near midday, and Deputy Harbormaster Farrell reported that at 4:45 p. m. it began to come over the wharf at the foot of St. Francis Street, although it had entered Water Street about a half hour earlier, probably through the sewers. The highest stage was reached at about 10:30 p. m. July 5, and there was no marked fall until about 2:30 a. m. July 6. The entire wholesale business district was inundated, and on St. Francis Street the water extended inland about four blocks. The water receded very slowly and only disappeared from the streets about 4 p. m. July 6. City Engineer Wright Smith contributes in Table 1 the measurements of the height of the tides which have occurred during the last six storms. He has not yet had time to check the last measurement.

TABLE 1.—Stages reached by tides accompanying recent storms at Mobile, Ala.

Year.	Above mean low tide.
1893.....	8.8
1901.....	8.23
1906.....	9.87
1909.....	8.7
1915.....	7.2
1916.....	11.6

THE DAMAGE AT MOBILE BY THE STORM.

The damage to buildings was probably more general than from any other storm, although only a few houses were demolished. Of the houses destroyed, the Lowenstein Building, valued at about \$30,000, was the greatest individual loss. Numerous tin roofs were rolled up and other roofs totally or partly torn off, so that few interiors of houses escaped damage by rain.

Nearly all merchants in the wholesale business district elevated their wares above the level of the highest tide, which occurred in 1906, but the unprecedented high water wet the lowermost goods, and the grain in sacks was damaged to the fourth layer of sacks above the one submerged. All electric services were totally crippled, the telegraph lines going down at about noon July 5. The Western Union Telegraph Co. reestablished communication over one wire at about 11 p. m. July 7. Railroad traffic was suspended, and the heavy rains on July 7 again deterred the movement of trains. The wharves suffered greater damage than from any other storm, and shipping suffered considerably, although not so much as in the storm of 1906. The official list of the American vessels wrecked, kept in the office of the collector of customs, will not be completed for a month, as, owing to the disturbed conditions, returns are not being made by vessel owners. Through observation and inquiry of boatmen information was obtained for the following list of marine disasters: Two bay steamships are probably complete losses, and four others are sunk or aground; four tugs are sunk or aground; one Russian ship, one Russian bark, and the four-masted schooner *Elizabeth Doyle* are aground; 12 barges, mostly laden with coal, are sunk or aground; two river steamers are on top of the wharf; four large yachts and numerous small craft are sunk or aground.

The day preceding the storm being a holiday some of the tugs were without steam, and the prevalent opinion that a severe storm could not occur so early in the year resulted in many vessel masters not taking sufficient precautions.

The estimated damage to buildings, street paving, and electric services by wind and tide is \$1,300,000; the damage to merchandise by tide is \$500,000 and by rain \$200,000; the damage to docks and railroads entering Mobile, \$200,000; damage to vessels, \$150,000; the loss of timber floated away, \$75,000. Generally the parties that lost are not disposed to make known the extent of their losses, and more difficulty was experienced in securing information than following any storm since that of 1906. The estimates of the damage made by different parties differ by as much as \$2,000,000 or \$3,000,000.

At Mobile one death by drowning occurred, that of a colored woman blown from a house boat. Three other bodies of drowned persons were found near Mobile, but these may have come from the lower bay, as parts of a barge that was near Fort Morgan were found at Mobile.

VALUE OF THE WARNINGS.

The warnings issued were instrumental in saving lives and probably preventing some marine disasters. The protection of goods from high tides at Mobile probably prevented a loss of \$100,000.

INFORMATION FROM STORM-WARNING SUBSTATIONS.

On the Mississippi coast the severity of the storm decreased rapidly west of Pascagoula. Based principally on reports from the storm-warning displaymen, the following is an account of the damage at the storm-warning substations:

Fort Morgan.—The storm was severe from early in the morning. Considerable damage was done to property. In lower Mobile Bay, near Fort Morgan, the barge *Harry Morse* and the schooner *Emma Lord* were sunk and the number of lives lost is probably 11. The barometer was 29.50 inches at midnight, July 4, and 28.38 at 4 p. m. July 5. (The instrument will be compared with the standard.)

Pascagoula.—Half of the buildings in the town were damaged. The monetary loss is estimated at \$40,000, and an equal loss in the near-by town of Moss Point. The wind veered from northeast to southwest and there was a lull for about 20 minutes between 4 and 5 p. m.

Biloxi.—The property loss within the city limits by wind and water is estimated at \$10,000. One person was killed. The tide was about 3 feet lower than during the storm of September, 1915.

Gulfport.—The estimated damage to property is \$40,000.

Pass Christian.—The estimated damage to property is about \$10,000; the tides were not high.

Bay St. Louis.—The damage by storm was slight, probably amounting to \$200.

THE TROPICAL HURRICANE OF JULY 5, 1916, IN LOUISIANA.

By ISAAC M. CLINE, District Forecaster.

(Dated: Weather Bureau Office, New Orleans, La., Aug. 3, 1916.)

The western segment of an unusually severe tropical storm passed over southeastern Louisiana July 5, 1916. Advisory warnings giving the location and probable movement of the storm were received from the Central Office, July 2, 3, and 4, telegraphed to all coast stations, radiographed to ships at sea, telephoned to shipowners and agents, and published in the daily papers.

The following specific warnings were distributed to the public:

July 4. Hoist northeast storm warnings Louisiana coast, 8:15 p. m. Disturbance probably centered near middle Gulf, moving northwest. Caution is advised.

July 5. Advisory Louisiana and Texas coast stations, 9 a. m. Tropical storm nearing middle Gulf coast, moving northwest. Strong northerly winds and moderate gales on the Louisiana coast, with rising tide to-day and to-night. Moderate to fresh northerly winds on the Texas coast.

July 5. Change to hurricane warning, 11 a. m., Louisiana coast. Notify people in exposed localities. High tides and hurricane winds indicated this afternoon and to-night. Shipping should remain in port.

This warning was given an extraordinary distribution. It was telephoned to Fishers' Landing and Harvey's Canal, with instructions to send to Grand Isle by motor boat. Another motor boat was started out from Myrtle Grove with instructions to distribute warnings throughout the Barataria section and reach Grand Isle if possible. This boat carried the warning 18 miles, distributing it to fishing camps, and returned, covering a distance of 36 miles. It was sent to all telephone exchanges in south Louisiana at Government expense, and Superintendent Baird instructed all managers of telephone exchanges to which the warnings had been sent to give the warnings the widest possible distribution. Mr. W. A. Porteous, manager of the Western Union Telegraph Co., Mr. N. E. Church, manager of the Postal Telegraph Co., and Mr. Charles Marshall of the Louisville & Nashville Railroad, sent the warning to all managers and station agents without expense to the United States, with instructions to advise their patrons.

The warnings were heeded generally. Small craft put into safer harbors, large vessels stopped in the Mississippi at Pilottown or remained at New Orleans until advised

that it was safe to proceed. The Louisville & Nashville Railroad suspended trains early in the day and the New Orleans & Northeastern Railroad suspended all trains crossing Lake Pontchartrain early in the afternoon. As a precautionary measure, women and children working in the department stores and factories were, on the advice of the Weather Bureau, sent to their homes early in the afternoon.

The center of the storm moved inland somewhere near and east of Gulfport, Miss., and New Orleans, being on the rim of the hurricane, did not experience high winds. The maximum wind velocity at New Orleans during the hurricane was 35 miles per hour from the northwest, at 4:03 p. m. The wind direction was from the northeast from midnight until 8 a. m., north from 8 a. m., until 12 noon, northwest until 10 p. m., then west at 11 p. m., and southwest at midnight. Light misting rain fell most of the day. The barometer fell steadily but slowly from noon, July 4, the rate of fall increasing after midnight to about 0.15 inch an hour and continuing at that rate until 5:15 p. m. of the 5th, when the sea-level pressure was 29.41 inches, which is the lowest pressure recorded at New Orleans for any July.

At Burrwood the wind reached storm velocities about 1 a. m., July 5; verifying velocities occurred at frequent intervals during the early morning, and at 9 a. m. the wind increased to a gale, with maximum velocities during the hours ending at 9 a. m., 58; 10 a. m., 60; 11 a. m., 63; 12 noon, 62; 1 p. m., 60; 2 p. m., 58; 3 p. m., 56; 4 p. m., 49; 5 p. m., 46; and 6 p. m., 37. After 6 p. m. the wind gradually subsided. On account of trouble with the wireless apparatus at Burrwood we were unable to communicate with that station after 7 p. m., July 4. All persons at Burrwood, including the observer, went aboard the dredge *New Orleans* as a precautionary measure, and no barometer readings were taken at Burrwood between 2:30 a. m., July 5, and 2 p. m., July 5, when the barometer was rising again.

TABLE 1.—Barometer readings at Burrwood, La.

Date.	Time.	Barometer.	Wind direction.	Date.	Time.	Barometer.	Wind direction.
1916.				1916.			
July 4.....	P. M.	Inches.		July 4.....	P. M.	Inches.	
	12:45	29.77	ne.		8:30	29.65	n.
	1:15	29.78	ne.		9:30	29.63	n.
	1:45	29.77	ne.		11:30	29.59	n.
	2:15	29.74	ne.		A. M.		
	2:45	29.72	ne.	July 5.....	12:30	29.53	n.
	3:15	29.71	ne.		1:00	29.50	n.
	4:00	29.69	ne.		2:00	29.47	n.
	4:30	29.69	ne.		2:30	29.43	n.
	5:30	29.67	ne.		P. M.		
	6:00	29.66	n.		2:00	29.38	sw.
	6:30	29.65	n.				
	7:00	29.65	n.				

There was neither lightning nor thunder at Burrwood. The tide was 2.2 feet above the normal.

White Harbor.—The following report has been furnished this office by Prof. Flonan Schaffter from White Harbor (near Gulfport), Miss.:

On July 5 at 7 a. m. the tide was unusually high, the barometer was 29.55 inches, and the wind northeast; the barometer readings were as follows: 8 a. m., 29.46; 11 a. m., 29.40; noon, 29.32; 12:50 p. m., 29.22; 1:50 p. m., 29.13; 2 p. m., 29.10, and wind shifting to the north; 2:05 p. m., 29.02; 4:10 p. m., 28.88; 5 p. m., 28.85, the lowest barometer reading during the storm, and the wind shifting from north to northwest; 8:20 p. m., 29 inches; July 6, 12:45 a. m., 29.38, wind west to southwest; 7 a. m., 29.64.

Pass Christian, Miss.—Dr. A. R. Robertson, Pass Christian, Miss., has furnished the following record of observations made during the passage of the hurricane:

TABLE 2.—Record of pressure and wind at Pass Christian, Miss., July 5, 1916.

Date.	Time.	Barometer.	Wind direction.	Date.	Time.	Barometer.	Wind direction.
1916.				1916.			
July 5.....	A. M.	Inches.		July 5.....	P. M.	Inches.	
	8:00	29.65	ne.		3:30	29.12	n to nw.
	9:00	29.60	ne.		3:45	29.10	n to nw.
	10:30	29.52	n to ne.		4:00	29.08	nw.
	NOON.	29.42	n to ne.		4:15	29.06	nw.
					4:30	29.04	nw.
	P. M.				4:45	29.03	nw.
	12:15	29.40	n to ne.		5:00	29.03	nw.
	12:30	29.38	n to ne.		5:15	29.03	nw.
	12:45	29.38	n to ne.		5:30	29.04	w to nw.
	1:00	29.36	n.		5:45	29.03	nw.
	1:15	29.36	n.		6:00	29.04	w to nw.
	1:30	29.34	n.		6:15	29.04	w to nw.
	1:45	29.32	n.		6:30	29.05	w to nw.
	2:00	29.28	n.		7:00	29.10	(¹)
	2:15	29.26	n.		8:30	29.16	(¹)
	2:30	29.23	n.		9:00	29.20	(¹)
	2:45	29.19	n.		10:00	29.28	(¹)
	3:00	29.16	n to nw.		11:45	29.44	w.
	3:15	29.13	n to nw.				

¹ Wind backing to the west.

SOUTH CAROLINA HURRICANE OF JULY 13-14, 1916.

By J. H. SCOTT, Meteorologist.

[Dated Weather Bureau Office, Charleston, S. C., July 22, 1916.]

The hurricane that struck the South Carolina coast on July 13, 1916, and whose center passed inland during the early hours of the 14th was remarkable in a number of particulars. It was of unusual severity, though its path of destructiveness was comparatively narrow. Few, if any, of the usual premonitory signs were present. No unusual cloud formation or movement was observed locally in advance of the storm and even during the afternoon of the 13th, when fresh to strong gales were blowing, it was a subject of remark that the cloud movement appeared sluggish. The tides preceding the storm were only slightly above the predicted heights—a condition that invariably obtains during the prevalence of easterly winds, which had been blowing for a day or two. Variation of the tide from the predicted height at the customhouse dock, as obtained from United States Assistant Engineer Allen, was as follows: Low tide, about midnight 12th-13th, normal; high tide, morning of 13th, +0.8 foot; low tide, midday 13th, +1.3 feet; high tide, evening of 13th, +2.3 feet (actual height 8.5 feet, which was the highest during the hurricane); low tide, due 0^h 57^m a. m. of the 14th, +0.9 foot, occurred about 2 hours and 45 minutes after the predicted time because of westerly winds. High tide morning of the 14th was +0.5 foot.

The sky presented no unusual appearance at sunrise and sunset preceding or during the storm. The first indication of the advance of the hurricane was the abnormal pressure fall along the South Atlantic coast during the 12 hours ending at 8 a. m. of the 13th. Special observations were sent at 11 a. m., 2 p. m., and 4 p. m. on telegraphic orders, and another at 12:28 p. m. in accordance with existing instructions. Orders to hoist northeast storm warnings at 12:30 p. m. were received at 12:45 p. m. and orders to hoist hurricane warnings at 7 p. m. were received at that hour. Both received immediate attention. The hurricane warnings were distributed widely, though owing to a number of adverse circumstances it was not possible to carry out the pre-arranged plan in full.

Effort to communicate with McClellanville by telephone failed owing to the prostrated lines; and W. A.

King, of Mount Pleasant, who had agreed in advance to carry the warnings, upon being called upon to perform the service stated that it was utterly impossible for any person to make the trip that night on account of the fallen timber. He had been up that way in the afternoon and had great difficulty in returning. All efforts to induce a courier to go to Yonges Island met similar defeat. The warnings reached Martins Point by telephone, however, and were distributed widely over that section. Telegraph offices were closed, and upon notification that delivery was impossible before morning telegrams to several places were ordered canceled. Unavailing effort was made to reach Georgetown by telephone, but the telegraphed warnings reached that place.

In this city every available means was used for the distribution of the warnings, including rockets, fire bells, an electric advertising sign, the telephone, printed bulletins distributed by messenger, moving-picture screens, etc. Tugs that had promised, for a compensation, to distribute hurricane warnings and assist people from the islands to reach the city had already sought places of

to South Island was down; no vessel would undertake the trip to North Island or South Island, and no one would attempt the trip overland, so these stations did not receive the hurricane warnings, though the northeast storm warnings were displayed. There is no inclination to censure those who refused to attempt overland trips through wooded sections, for the undertaking would have been perilous in the extreme and probably impossible of accomplishment.

At Charleston during the forenoon of the 13th there was a gradual fall in the barometer with moderate to fresh northeast winds. Rain began to fall at 12:11 p. m. and became heavy at 12:17 p. m., coincident with a sudden increase in the wind, which reached a velocity of 47 miles per hour about 12:20 p. m. Northeast storm warnings were ordered by the local official at 12:15 p. m. and were hoisted at 12:20 p. m. The rain ended at 12:32 p. m. and the wind subsided, but another heavy shower began at 12:58 p. m. with increasing wind and a velocity of 52 miles was attained shortly before 2 p. m. The wind again diminished and was below a

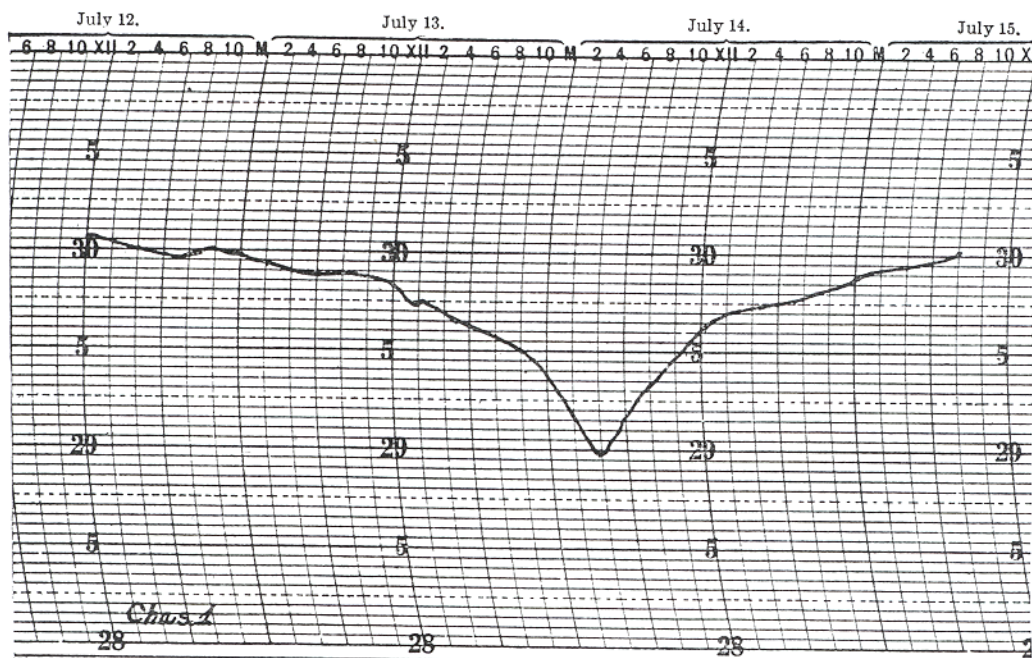


FIG. 1.—Barogram at Charleston, S. C., July 13-14, 1916. (Sea-level pressure and 75th mer. time.)

safety for themselves, and their masters could not be communicated with by telephone. A. R. W. Stoesen, messenger boy, was sent in search of them with instructions to get the lighthouse tender *Cypress* if they were not at their wharves. This he did in the raging storm, running nearly a mile to her dock on Ashley River. Capt. J. P. Johnson, of the *Cypress*, prepared at once to go to Sullivans Island, and safely transported to the city all who would come. Warnings had previously been disseminated there, and the cooperation of the military authorities at the Army post had been secured in collecting the people in places of safety. About 125 returned on the *Cypress* and large numbers spent the night in the fort. The regular trolley and ferry service to Mount Pleasant and the islands had been discontinued with the 5 o'clock p. m. trip from the city, the poles bearing the trolley wires from Mount Pleasant to Sullivans Island having gone down.

From Georgetown the tug *E. T. Williams* was sent to Waverly Mills up the Waccamaw River, and a courier walked about 3 miles across to warn the residents of Pawleys Island and Murrels Inlet. The telephone line

36-mile velocity for nearly an hour, but began to increase about 3:30 p. m., reaching 58 miles before 4 p. m., and 64 miles about 4:35 p. m. This was the highest velocity recorded from the northeast, but the wind held steadily in that quarter until about 10 p. m., when it began to shift to north, and by 2 a. m. of the 14th was becoming northwest, reaching the highest velocity from that direction, 64 miles, shortly after 2 a. m. The extreme velocity was 76 miles from the northwest at 2:08 a. m. It is reasonably certain that the velocity at this time was the highest during the storm, being considerably higher than during the preceding afternoon, but owing to the position of the instruments on the eastern waterfront, with the city to the west and northwest, the difference is not indicated in the record.

The wind then diminished very slowly, notwithstanding the fact that the barometer continued to fall until 4 a. m., when it reached the lowest point, 29.02 inches, reduced. Velocities of 50 miles or above were maintained until 6 a. m., and by about 11 a. m. the wind had fallen to 36 miles per hour, though it exceeded that velocity occasionally thereafter. The wind began to

shift to west about 4 a. m. and to southwest between 5 and 6 a. m., continuing from that direction until about 2 p. m., when it became south. It was fortunate for Charleston and the adjacent islands that the wind shifted from easterly to westerly directions before the time of high tide on the morning of the 14th, thus preventing a disastrous inundation.

The fall in the barometer increased during the afternoon of the 13th and became more rapid after 10 p. m., when the reading was 29.54 inches. From 12:30 a. m. to 5 a. m. of the 14th readings were made at half-hour intervals and were as follows: 12:30 a. m., 29.32; 1 a. m., 29.28; 1:30 a. m., 29.22; 2 a. m., 29.12; 2:30 a. m., 29.08; 3 a. m., 29.05; 3:30 a. m., 29.03; 4 a. m., 29.02; 4:30 a. m., 29.09; 5 a. m., 29.13. The rise after 4 a. m. was steady; at 8 a. m. the reading was 29.40, at noon 29.68, at 4 p. m. 29.75, and at 8 p. m. 29.84.

The displayman at Georgetown reports readings as follows: 7 p. m. of the 13th, 29.52; 9 p. m., 29.50; midnight, 29.38; 3 a. m., 14th, 29. The readings are not carried further, and it is not stated what barometer was used, though it is stated that it reads 0.16 inch too low.

Following the heavy showers at the beginning of the storm, the rain during the afternoon of the 13th was not heavy and ceased at 5:15 p. m. It began again at 7:40 p. m. and continued steadily throughout the storm period, the total amount of precipitation in connection with the storm being 4.33 inches.

The material damage locally was not great. Most houses suffered minor damage to roofs and consequent water damage. Some signs were blown down and a few valuable plate-glass windows were broken. No large vessels suffered material injury, though a number of small boats were sunk at their wharves, and a few of them were crushed, though most of them suffered only minor damage. The telephone system was badly deranged, 1,500 phones being placed out of commission. Wire communication with the outside world was practically cut off, but was restored within a few hours, though service has been extremely poor ever since the storm, due partly, no doubt, to the flood situation. One of the most lamentable results of the storm from a community point of view was the damage to shade trees, the soaking rain and the shifting winds combining to uproot many of them. There were two lives lost in Charleston and vicinity, one negro man being electrocuted when he came in contact with a live wire, while another, who was on a gravel barge in the harbor and refused to leave it in a small boat when his companion escaped, was drowned when the barge sank. The beach resorts weathered the storm with no loss of life and no great material damage. Great credit is due Capt. Johnson of the lighthouse tender *Cypress* for making a perilous trip to Sullivans Island during the night of the 13th at the request of this office to bring back those who wished to come to the city. The *Cypress* and the tug *Wellington* of Philadelphia also performed heroic rescue work in saving all on board the naval auxiliary *Hector*, which was wrecked about 8 miles north of Cape Romain gas buoy.

The damage south of Charleston to North Edisto River seems to have been confined almost wholly to crop injury. To the northward the destruction was much greater. Large tracts of cultivated land in the McClellanville section were inundated Friday morning, causing a total loss of crops. Water stood 4 or 5 feet deep in the town and left a heavy deposit of sea sedge covering dead animals and fowls. The tide is said to have been higher than in 1893 or 1911. Energetic measures have been taken to avoid pestilence. The crop damage from about 15 or 20 miles northeast of Charleston on to

McClellanville and the Santee River is estimated by those competent to judge at from 75 to 90 per cent. Almost all the trees in McClellanville were uprooted. Numerous houses were blown down, but they were mostly of flimsy construction. Loss of live stock was rather heavy from wrecking of barns, and some hogs and other small animals were drowned. Notwithstanding the great material damage there was no loss of human life.

In Georgetown the damage was apparently little worse than in Charleston, except that the tide rose higher and is said to have damaged some goods in stores on the water front, though the displayman does not mention this in his report. In fact, he states that the most serious damage was the blowing down of hundreds of shade trees and a few negro shacks. The wind at Georgetown shifted from northeast to southeast at about 2:45 a. m. The yacht *Palmetto* and a few smaller boats were sunk, but were not a total loss. The Atlantic Coast Lumber Corporation and the Winyah Lumber Co. were perhaps the heaviest individual losers, and their greatest loss is in fallen timber.

North of Georgetown the storm was less severe, though the tide was very high at Pawleys Island and Murrels Inlet. No damage of consequence occurred there, however, or at Myrtle Beach, farther up the coast.

The hurricane is believed to have been one of the most severe that has visited this coast since the Weather Bureau was established, but its destructive effects were confined to unusually narrow limits. This is due partly at least to the fact that its course was practically normal to the coast line. Its center is thought to have passed inland over Bulls Bay, about 25 miles northeast of Charleston and some 10 miles southwest of McClellanville.

The barges *Northwest* and *Southwest* broke away from the tug *Wellington*, of Philadelphia, about 9 p. m. of the 13th and grounded on the shoals off Bulls Bay about 6 miles south of Cape Romain. Each barge was manned by five men. The men from the *Northwest* drifted ashore on Sandy Point, and after facing death from hunger and thirst for nearly three days two of them swam the inlet to Cape Romain Sunday afternoon and procured the light keeper's assistance in rescuing the other three. The five men on the *Southwest* were undoubtedly lost, and the bodies of three of them have washed ashore. Aside from the two deaths previously reported in Charleston and vicinity, this appears to have been the total toll in lives taken by the storm proper, though many lives were lost in the floods resulting from its inland progress.

The two barges that have been mentioned and the U. S. S. *Hector* were apparently the only wrecks at sea.

It is practically impossible at this time to estimate with any degree of accuracy the total losses occasioned by the hurricane. The *Hector* and the two barges that were lost were together worth more than a half million dollars. The losses in Charleston and vicinity are estimated at less than \$100,000, including two large fires incidental to the storm. Twenty-five thousand dollars will probably cover the losses at Georgetown. McClellanville, though much harder hit, is a smaller town and a similar amount will probably cover the losses there. This does not take into account the loss of crops and standing timber, which is hard to determine, but which, with the damage to land by salt water, will probably run into the millions. It will certainly run high into the millions if the floods which resulted from the storm's inland progress be taken into account.

In justice to the office force I wish to say that both the assistants and the messenger boy performed their full duty cheerfully without considering personal risk or comfort throughout the trying period.

SECTION III.—FORECASTS.

FORECASTS AND WARNINGS FOR AUGUST, 1916.

By ALFRED J. HENRY, Supervising Forecaster.

[Dated Weather Bureau, Washington, Sept. 19, 1916.]

HIGHS.

During the month of August, 1916, nine highs, mostly of feeble intensity, passed east-southeast as shown by Chart II (XLIV-86). The main path of the highs was southeastward through the Dakotas and the Middle Missouri Valley but after leaving that region they diminished greatly in intensity.

LOWS.

Sixteen primary LOWS and one secondary, were charted during the month. This number includes two tropical cyclones, Nos. VIII and XIII of Chart III (XLIV-87), but does not include the tropical cyclone of August 29-31 that passed westward over the Caribbean and apparently dissipated over the Yucatan Peninsula on September 1.

Practically all of the extratropical LOWS of the month passed eastward north of the Great Lakes and there was a marked tendency toward the development of a trough of low pressure extending to the southwest of the center of the LOW as soon as the latter passed the Great Lakes. In August 50 per cent of the LOWS which appear on the daily weather maps of the Weather Bureau have their origin in the Province of Alberta. The remaining 50 per cent have their apparent origin over the north Pacific Coast States, the northern and middle Rocky Mountain regions, respectively, or they may develop as secondary disturbances over the Central Valleys east of the Plains States.

The LOWS of the current month were largely of the Alberta type and their eastward movement after reaching the Missouri Valley was well to the northward of the Great Lakes. The north component of the LOWS and the fact that not a single disturbance developed in the Gulf and South Atlantic States or moved northeastward from that region are the prominent features of August weather in the United States.

Tropical cyclone of August 12-18.

Three tropical cyclones appeared during the month. The first, a portion of whose path is shown as No. VIII of Chart III, was first observed on the morning of the 12th in the vicinity of Barbados; it passed westward a short distance south of Jamaica on the 15th and into the Gulf of Mexico by way of the Yucatan Channel on the night of the 16th; it was approaching the south Texas coast on the morning of the 18th, and passed inland between Corpus Christi and Brownsville the afternoon and evening of the 18th.

Advices of the probable location and movement of this hurricane were sent to all Gulf ports beginning on the 13th and continuing twice daily until definite warnings were issued on the morning of the 18th. A notification of the approach of this storm was also wired to the commanding general at San Antonio, Tex. Some of these advices are published in District Forecaster Cline's report, page 463.

Six lives were lost by the foundering of the coastwise steamer *Pilot Boy* off Port Aransas, Tex.; three additional lives were lost by drowning along the coast near Corpus Christi, Tex., and six at various interior points, as a result of hurricane winds in the lower Rio Grande Valley.

Newspaper reports place the damage sustained in southwest Texas at \$1,800,000. The damage, while largely confined to coast regions, was more or less general over a wide area. In the interior, crops were badly damaged by wind and rain and windmills, fences, and barns were blown down.

Observer W. F. Lehman, in charge of the Weather Bureau office at Corpus Christi, makes the following report on the storm.

Corpus Christi, Tex.—The first indications of the approach of the tropical cyclone that visited the western Texas coast region on August 18, 1916, were observed at Corpus Christi on the night of the 17th. The barograph recorded a wavering line, scarcely differing more than one-hundredth from a straight line, from 7 p. m. till 12 midnight, instead of showing the usual rise of about six-hundredths of an inch between 7 p. m. and 10 p. m. The wind, which had been light to gentle easterly during the day, shifted to northeast about 10 p. m. and to the north at 11 p. m. A clear sky with a few strato-cumulus clouds had prevailed since 5 p. m. and was still clear at midnight. Cirrus and cirro-cumulus clouds from the east had been observed during the day, but their prevailing direction had been easterly since the middle of July.

In the early morning of the 18th the barometer began to fall slowly, and the wind, still from the north, increased from light at 1 a. m. to 22 miles at 7 a. m. Loudness also increased. Coming from the east, a layer of dense alto-stratus gradually advanced with a well-defined west front. At 5 a. m. about four tenths of clear sky could still be observed. The clouds soon assumed the shape and density of strato-cumulus, and at the time of the morning observation covered eight-tenths of the sky, with a sharply defined area of clear sky in the west.

The first light shower occurred at 7:45 a. m., and a thunderstorm, coming from the northeast and attended by moderate rainfall, passed over the city between 9:40 and 10:35 a. m. The wind, which had reached a velocity of 40 miles at 9:35 a. m., changed to light and moderate northeast during the passage of the thunderstorm, but soon resumed its north direction and squally character.

The barometer, after registering the usual thunderstorm nose, fell rapidly, and the wind increased in intensity, attended from 11:55 a. m. on by a steady rain which did not end until late at night. At 1:53 p. m. a maximum velocity of 64 miles was recorded with an extreme of 70 miles. The direction of the wind soon after changed to northeast and its velocity decreased to the force of a strong gale from 3 to 5:30 p. m.

The first squall of hurricane force occurred at 5:45 p. m. It was the beginning of straight east winds, veering occasionally between east-northeast and east by south. The barometer reached its lowest point, 29.05 inches—29.07 reduced to sea level—at 6:15 p. m., but the wind attained its highest velocities during the subsequent two hours and a half. Estimated maximum velocities of 90 miles were reached at 6:50, 7:18, 8:15, and from 8:40 to 8:50 p. m., the barometer rising rapidly after 6:45 p. m.

From 6:30 p. m. on all the meteorological notes except the barograph curve had to be recorded by eye observation or estimation, since the wind instruments were wrecked and the windowpanes in the instrument room were shattered, burying the mechanism of the automatically registering instrument under glass splinters. The barometer box was fixed solid to the wall, and as there was no safer place to take the barometers to—it was not thought that the windows in the other office rooms would hold out much longer—they were well protected and the room was closed up.

After 9 p. m. the wind subsided, and at 11:30 p. m. it shifted to a southerly direction. The wind continued to blow in gusts till late in the forenoon of the 19th and became light after 7 p. m. A period of unusually light winds and calms, lasting five days, followed the storm.

The total rainfall for the day amounted to 1.58 inches, but this record is unreliable, as much of the rain was blown straight across the roof of the building, and such quantities as fell into the rain gage were mingled with salt-water particles from the bay, only a block distant from the

office. The water drawn from the rain gage had a decidedly brackish taste.

From reports of reliable observers, gathered at this office, the storm center passed inland a little south of Riviera, situated 45 miles south of Corpus Christi. At this place the wind blew from the north until about 8 p. m. and after a half hour's easterly direction came straight from the south. At the office of the Santa Gertrudis ranch, at Kingsville, 14 miles north of Riviera, the aneroid barometer was carefully watched by Mr. J. B. Wright, the manager of the ranch, and he took the lowest reading of 27.70 inches at 8:15 p. m. This instrument showed, on comparison, that it registered three-tenths too low, and it was sent to this office for adjustment. After being adjusted two day's observations and comparisons failed to show any difference in readings between our station barometer and this aneroid.

Hurricane warnings were received and sent out early in the forenoon. Considering local weather conditions and the 7 a. m. barometer readings of regular Weather Bureau stations on the Texas coast, there could be doubt about the course of the storm. It was also expected that telegraph wires would go down early and that the storm, which few, if any, had apprehended only 12 hours before, would reach its fullest strength on the coast about sunset. The coast places were warned first. Some fishermen had already ventured out at dawn in the bay and the lagunes; of these two were drowned. Then warnings that a hurricane was approaching the Texas coast between Corpus Christi and Brownsville and that its full force might be expected sometime at night were sent out for dissemination to all places from Calhoun to Cameron Counties that could be reached by telegraph or telephone. Even as early as 10 a. m. about 20 of the addresses to be advised by telegraph could not be reached on account of wire trouble and had to be sent by telephone.

At 1 p. m. it was thought expedient to warn the city authorities that the worst might be expected between sunset and midnight and that people living in light frame houses should seek shelter in substantial brick buildings for the night. A volunteer brigade of about 100 automobiles was organized, and these were busy from 1 till 5 p. m. in bringing women and children from the outskirts of the city to the safer buildings of the business section. This work was greatly aided by the decrease in wind velocities between 3 and 5:30 p. m. (City Hall, hotels, banks, and schoolhouses were filled with refugees, which, while not comfortable, felt at least safe and at ease.

Of the people that thronged the local office of the Weather Bureau during the day a surprisingly large percentage were visitors who had spent their last summer's vacation at Galveston and had come to Corpus Christi this year in order to escape another hurricane. It was the settled conviction of even the oldest inhabitants that Corpus Christi lay outside of the path of destructive storms. Thus many did not trouble themselves with protecting such property as could have been saved, and afterwards were glad that they and their families escaped with their bare lives.

Of the death toll exacted by the storm: six of the crew of the steamboat *Pilot Boy*, coming from Galveston, forewarned, perished when the boat was wrecked in the entrance of Port Aransas Harbor. The two fishermen mentioned before and a boy aged 14 complete the list of those drowned. Three unidentified Mexicans were killed in Willacy County, and an aged Mexican and his wife were found dead in their demolished home 7 miles southeast of Alice, Jim Wells County. Three warnings had been sent to Alice and were acknowledged with thanks. The death of an unidentified Mexican woman was reported from San Diego, Duval County.

The property loss in the entire hurricane affected district is estimated at \$1,600,000, the cities of Bishop, Kingsville, and Corpus Christi being the largest sufferers. In Corpus Christi it was the water front that sustained the heaviest damage. All the wharves and most of the buildings on the wharves were destroyed, even the solid timber head of the municipal wharf was unfloored, taking down the storm-warning display tower. Hardly a property in Corpus Christi escaped without damage of some kind, and vegetation where not destroyed suffered heavily. Many of the picturesque salt cedars, the pride of Corpus Christi, were blown down.

There can be no question but that the storm was a fully developed hurricane with a central pressure at least 1 inch lower than that observed at Corpus Christi. The relatively low property losses along the coast must be ascribed to the rapidity with which the storm advanced and passed. Because of this rapidity of movement its chance of creating a big tidal wave were greatly diminished. Also it must be borne in mind that the whole length of the Texas coast is protected by sand islands stretching from the mouth of the Rio Grande to Galveston, with few inlets and sparsely settled.—*W. F. Lehman.*

After passing inland a short distance south of Corpus Christi, the cyclone continued to move in a west-northwest direction, reaching Del Rio, Tex., north latitude 29° 20', west longitude 100° 53', at about 7:30 a. m. local mean time August 19, with a minimum pressure of

28.69 inches. Since it passed Corpus Christi, 200 miles distant, 12 hours earlier, we may assign it a movement of about 17 miles per hour. The recovery of the pressure after the passage of the center of the storm was extremely rapid. By 10 a. m. the barometer was slightly higher than the value it had 24 hours previous. The next observing station in the path of the storm is El Paso, Tex., distant about 300 miles. The barograph at that and other stations in that vicinity do not show any trace of the storm in question; we must therefore consider that it dissipated over southwest Texas during the daylight hours of the 19th.

It is worthy of note that all three tropical cyclones of August, 1916, were characterized by remarkably small diameters and naturally extremely steep barometric gradients near the center only. Two of them surely, and possibly the third, passed into the eastern Caribbean with practically no premonitory signs, and by reason of their small diameters, and the fact that the centers did not closely approach any of the network of land stations except for a very brief period, the location of the center of the storm was in each case a very unsatisfactory matter.

Porto Rican tropical cyclone of August 22, 1916.

The history of the second tropical cyclone, charted as Low No. XIII, is enveloped in more or less obscurity. Advice of this storm was received from Observer F. E. Hartwell, official in charge, San Juan, P. R., who sent a special observation to the Washington office at 6 a. m., Tuesday, August 22, and later the following report—

Tuesday, 22d.—Hurricane of comparatively small diameter passed over Porto Rico this forenoon, vortex entering the island at about Naguabo and leaving between Arecibo and Isabella. Wind velocity at San Juan 90 miles per hour for about 45 minutes. Highest 10-minute period about 92 miles per hour. Much damage was done throughout the island, a million dollars being a conservative estimate of the money loss. Area of destruction was probably 45 or 50 miles wide and time of passing about two and a quarter hours. The rainfall at San Juan was comparatively light, no excessive falls occurring, and the total was less than 2 inches, but reports of as much as 7 to 9 inches have since been received from the interior of the island.—*F. E. Hartwell, Observer.*

The barogram for San Juan gave no indication of the approach of a disturbance until after midnight of the 21st, when it began to fall slowly. By 6 a. m. of August 22 the pressure was falling quite sharply, the lowest point, 29.44 inches, being reached at 7 a. m. Thereafter the rise was as rapid as the previous fall had been. By 8 o'clock the barometer was practically normal. After leaving Porto Rico on the morning of the 22d, the center of the storm did not approach any of the meteorological stations in the Bahamas or Cuba. Slight indications of its presence northwest of Haiti came to hand; continuous watch on the south Florida coast, while failing to show the presence of a tropical cyclone, did indicate the presence of a feeble disturbance east of the Florida peninsula on the 25th and 26th.

Tropical cyclone of August 28–September 1.

The third tropical cyclone of the month was indicated by cable reports from the Windward Islands on the morning of the 29th, as being south of and near Porto Rico. Mail reports just received show that an intense storm passed over Dominica during the afternoon and evening of the 28th. The hurricane advanced over the island with but little warning; a number of lives were lost and much property was destroyed on the northern and eastern sides.

Mr. W. A. R. Rawle, special meteorological observer at Roseau, furnishes the barogram reproduced as figure 1. Special interest attaches to this barogram, because it is typical of cyclones of extremely small diameter and rapid movement such as passed over Porto Rico, as detailed in the preceding paragraph. After passing to the westward of Jamaica on the 31st this storm was evidently dissipated over the Yucatan peninsula on September 1.

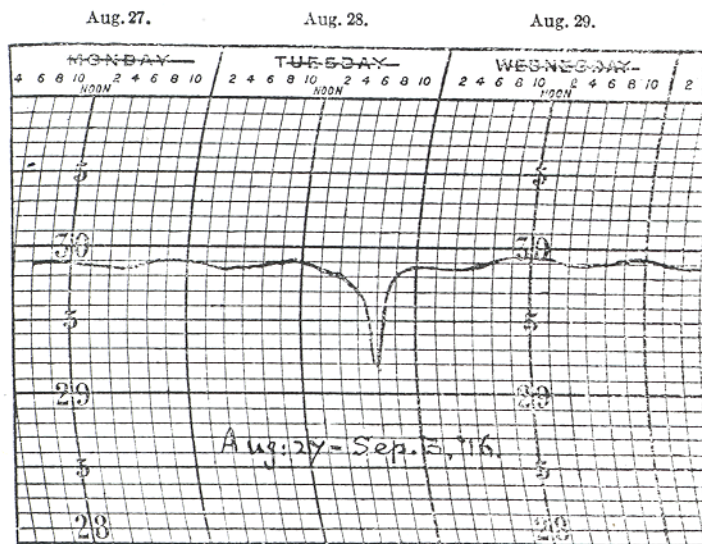


FIG. 1.—Barogram at Roseau, Dominica, Aug. 27-29, 1916.

Valuable reports of the cyclone of the 12th-18th were received by wireless from vessels of the United Fruit Co., especially the *Tenadores* and *Turrialba*, the former passing northward over the western Caribbean on the 16th and cutting the path of the hurricane at right angles and slightly to the rear of its center.

DISTRICT WARNINGS DURING AUGUST.

Chicago district.—Frost warnings were issued on the 13th and 27th for the entire cranberry marsh region of Wisconsin; for the marshes in central Wisconsin on the 26th; and on the 11th and 29th for the marshes of northwestern Wisconsin.

Fire-weather warnings for Minnesota were issued on August 9 and 10.—*Chas. L. Mitchell, assistant forecaster.*

Denver district.—The only warning issued during the month was that for frost in high places in Utah on the 18th.—*Frederick W. Brist, Assistant Forecaster.*

New Orleans district.—A small disturbance was central off the mouth of the Rio Grande Valley at 3 p. m. on August 5, and northeast storm warnings were ordered for the Texas coast stations at 8:30 p. m. The storm moved westward into Mexico and its passage was attended by storm winds on the Texas coast.

The only other feature of interest in this district during August was the tropical disturbance which moved inland near Corpus Christi, Tex., on the 18th.

Advisory warnings were received regularly on and after August 13 giving the location, probable intensity, and course of movement of the tropical disturbance.

On August 16 all vessels bound for the Yucatan Channel and Cuban ports were advised to delay sailing on account of the following advisory warning:

Advisory warning, 10 a. m. Tropical disturbance apparently central about 200 miles south of central Cuba, moving west-northwest. Storm is of greater intensity than indicated by earlier reports. It will doubtless reach the Yucatan Channel Thursday. Vessels bound for those waters should exercise caution.—*Henry.*

Advisory warnings were distributed on the 17th, and vessels were advised to delay sailing until further advised. Up to the night of August 17, 12 vessels, which had cleared from New Orleans, had anchored in the river in the vicinity of Pilottown and 8 to 10 steamers came into the river from the Gulf of Mexico to await further advices from the Weather Bureau, so that about 20 steamers were at anchor waiting for advices that it would be safe to proceed.

On August 18 the following warnings were issued:

Hoist northeast storm warnings, Texas coast, 7:40 a. m. Tropical disturbance probably moving north of west in west Gulf. Increasing winds with northeast gales and high tides to-day and to-night. Vessels bound from New Orleans to Cuban and Central American ports may proceed.—*Cline.*

Change to hurricane warnings 8:30 a. m., Corpus Christi to Brownsville. Center of disturbance as yet probably some distance east of western Texas coast.—*Henry.*

Some of the 20 vessels held at New Orleans would have encountered the hurricane in the Yucatan Channel and might have met the same fate as the *Admiral Clarke*, which was lost on the night of August 16. Vessel masters and agents who held their vessels until the routes were safe express the highest commendation for the manner in which the Weather Bureau kept them advised.—*I. M. Cline, District Forecaster.*

Portland (Oreg.) district.—August was, as usual, a quiet month in this district. Not so much rain fell as usual, but notwithstanding this fact there were few forest fires. No storm or small-craft warnings were issued and none was needed.

Fire-weather warnings were issued on the morning of the 19th, continued on the morning of the 21st, and concluded on the morning of the 23d. This series of fire warnings was the first issued this season; ordinarily it is necessary to issue them early in July.—*E. A. Beals, District Forecaster.*

San Francisco (Cal.) district.—Usually August is a very quiet month in this district and freer from rainy and unsettled weather than any other month. But August, 1916, was notable for the many periods of showery and unsettled weather in all sections. Warnings of showers were issued in southern California for the mountain sections on the 4th, 24th, and 26th, and were verified; but the light showers along the coast on the night of the 23d were not forecast.

In northern California the showers in the San Francisco Bay section on the 14th were not forecast and the warnings issued on the morning of that date were verified only in the mountain sections. The warnings issued on the 27th and 28th were verified in both northern California and Nevada.—*G. H. Willson, District Forecaster.*

SECTION III.—FORECASTS.

FORECASTS AND WARNINGS, SEPTEMBER, 1916.

By EDWARD H. BOWIE, Supervising Forecaster.

[Dated: Weather Bureau, Washington, October 21, 1916.]

The LOWS of September were not attended by violent winds. This was especially true of the tropical disturbances that reached the South Atlantic coast. One of these recurved east of the Bahamas and passed near Bermuda on the 23d, attended by destructive gales.

DISTRICT WARNINGS DURING SEPTEMBER.

Washington district.—The month opened with a tropical disturbance over the western Caribbean Sea and on the morning of the 1st the following advisory message was sent southern ports and distributed by wireless to vessels at sea:

The tropical disturbance over the Caribbean Sea is apparently central off the east coast of Yucatan and moving westward. Thus far it has not been attended by dangerous winds, although winds of moderate gale force have prevailed during the last 24 hours in the Florida Straits, the southeast portion of the Gulf of Mexico, and the Yucatan Channel.

On the morning of the 2d, advisory information to the effect that

The tropical disturbance has apparently crossed the Yucatan Peninsula to the Bay of Campeche, whence it will advance westward into Mexico and be dissipated,

was disseminated to southern ports and by wireless to vessels at sea.

On the morning of the 5th, northeast storm warnings were ordered for the South Atlantic coast between Savannah and Cape Hatteras and in the evening of the same day the display was extended northward to the Virginia capes. The necessity for the warnings arose from the presence of a disturbance of unknown intensity

off the Georgia coast. The center of this disturbance passed inland near Wilmington, N. C., during the night of the 5th and thereafter lost intensity. Winds of moderate gale force off the South Atlantic coast attended this disturbance during its march northward. On the 11th information to the effect that there were indications of a disturbance east of the Bahamas was sent Atlantic and Gulf ports, and on the morning of the 12th northeast storm warnings were ordered for the Atlantic coast between the Virginia capes and Jupiter Inlet. The center of this disturbance crossed the coast line near Jacksonville during the night of the 12th and thence moved westward into Alabama. Winds of gale force prevailed off the South Atlantic coast while the disturbance was offshore.

On the 20th information was issued to the effect that there were indications of a disturbance east of the island of St. Kitts, West Indies, and on the 23d advices were issued to the effect that this disturbance was recurving east of the Bahamas and moving toward Bermuda. The storm passed northeastward near Bermuda during the night of the 23d and was there attended by destructive gales.

WEST INDIAN STORMS.

Conditions were very active during much of the month over the Caribbean Sea, the West Indies, and that portion of the Atlantic Ocean south of latitude 35° , and several storms of hurricane character developed. Only one of these, however, reached the United States, and that one by way of the middle Gulf coast, an unusual course for the season of the year.

The first information of definite storm formation was obtained on the evening of October 2, when radio reports indicated the presence of a disturbance about 200 miles off the Georgia or South Carolina coast, and northeast storm warnings were immediately ordered from Norfolk to Charleston. More complete reports on the following morning indicated that center of the storm was off the Florida coast, farther south than had been first stated, and at 1 p. m. the northeast warnings were extended to Tybee Island and Savannah, Ga. At 8 p. m. October 3, there were some evidences of a further increase in the storm intensity, and the northeast warnings were continued from Norfolk to Charleston, and on the following morning at Tybee Island and Savannah, when the storm center was apparently a short distance off the Georgia coast. Up to this time strong northeast gales had been reported off the South Atlantic coast, and during the 4th moderate northeast gales occurred on the South Carolina and Georgia coast. By 8 p. m. of the 4th the storm had passed inland to northern Florida with greatly diminished energy, and the storm warnings were accordingly lowered.

The West Indian storm of October 7 to 12, 1916.

After a few days' respite another disturbance appeared in the vicinity of the Island of Dominica, the barometer at 8 a. m. October 7 reading 29.84 inches with calm air and rain falling. Notification was sent at once to the Windward Islands and to the United States Naval Radio Service, and special observations called for. Nothing of value was received during the day, but on the morning of the 8th it was apparent that the disturbance was near and east of Porto Rico and moving northwestward or northward. Advices to this effect were sent to West Indian points and to Weather Bureau stations on the Atlantic and Gulf coast and broadcast by United States Naval Radio. No further reports were received until the morning of the 9th, when the regular reports showed the storm to be still east of Porto Rico. Special evening reports afforded the first definite information as to the location of the storm center. These reports were to the effect that the storm center had passed over the Danish

West Indies, Santa Cruz reporting pressure of 29.42 inches at 3 p. m., with a gale, and St. Thomas, 29.26 inches at 6 p. m. This information was immediately given wide distribution over the water and along the coasts, and shipping warned to exercise great caution. By the morning of the 10th the storm had recurved slightly and had passed to the northeastward of Porto Rico. Nothing further was heard from the storm until the captain of the barque *Bellas* reported by mail that he had encountered it, in the form of a severe hurricane with southeast to southwest gales, on October 12 in latitude $27^{\circ} 40' N.$, longitude $62^{\circ} 20' W.$

The storm of October 9 to 19, 1916.

The point of origin of the next disturbance is uncertain. After the passage of the previous storm, pressure continued to fall over the Caribbean, especially to the southward of Jamaica, and on the morning of the 11th there were observed the first evidences of distinct cyclonic circulation with a center apparently a short distance south of Jamaica. The disturbance did not then appear to be of severe character, and no reports that were received later tended to disprove this contention. By the morning of the 13th the center of disturbance had apparently moved to the western Caribbean, probably to about latitude $16^{\circ} 30' N.$ and longitude $78^{\circ} W.$ Advisory warnings were then distributed and special reports called for. During the succeeding 24 hours the storm appeared to greatly increase in intensity and at 11:30 a. m. passed very close to Swan Island, the barometer reading at that place being 28.94 inches, with the wind blowing with hurricane force from the north. At 9 a. m. the radio apparatus was put out of commission by the storm and it became impossible to send any further reports.

Wind direction and force, weather, and barometer readings at Swan Island are given in Table 1.

TABLE 1.—Observations at Swan Island.

Date.	Barometer.	Wind.		Weather.
		Direction.	Force.	
	Inches.		0—12.	
Oct. 13, 8 a. m.	29.74	ne.....	1	Cloudy.
Oct. 13, 1:40 p. m.	29.70	n.....	2	Do.
Oct. 13, 3 p. m.	29.70	n.....	2	Do.
Oct. 14, 6 a. m.	29.37	n.....	10	Raining.
Oct. 14, 7 a. m.	29.36	n.....	10	Do.
Oct. 14, 8 a. m.	29.26	n.....	10	Do.
Oct. 14, 9 a. m.	29.20	n.....	12	Do.
Oct. 14, 11:30 a. m.	28.94	n.....	12	Do.
Oct. 14, 12:30 p. m.	29.03	e.....	12	Do.
Oct. 14, 1 p. m.	29.04	e.....	12	Do.
Oct. 14, 8 p. m.	29.32	e.....	12	Do.
Oct. 15, 8 a. m.	29.74	se.....	8	Do.

The observer at Swan Island reported that the wind blew at the rate of at least 100 miles an hour at times and with hurricane force from 8 a. m. of the 14th until 3 a. m. of the 15th.

Warnings were, of course, immediately sent out broadcast, and all shipping warned to take every precaution for safety. No evening reports were received during the 14th, but the warnings of the morning were repeated, and again on the afternoon and evening of the 15th, the center at the latter time being placed not far south of the Yucatan Channel. On the morning of the 16th the storm center was apparently crossing the northern portion of the Yucatan Peninsula, moving northwestward or northward, and warning advices were again issued morning and

evening. During the night of the 16th–17th the storm passed into the Gulf of Mexico, and at 8 a. m. of the 17th was apparently central at about latitude $24^{\circ} N.$, longitude $88^{\circ} 30' W.$ Northeast warnings were then ordered on the Gulf coast from Carrabelle, Fla., to Bay St. Louis, Miss. All interested were advised to take every precaution for safety, and all shipping advised to remain in port. These warnings were repeated in the afternoon and again at night. A late radio report from the steamship *El Rio* showed that at 1 a. m. of the 18th the storm center was not very far from latitude $27^{\circ} N.$, longitude $89^{\circ} W.$, with a barometer reading of 28.98 inches and a heavy easterly gale. By 8 a. m. of the 18th the storm center was in the vicinity of Fort Morgan, Ala., with the tide 2 feet above normal at Pensacola, Fla. Hurricane warnings were then ordered displayed from Apalachicola, Fla., to New Orleans, La.; northeast storm warnings were also ordered along the Atlantic coast from Savannah to Cape Henry, and special warnings of approaching destructive gales were sent to interior points in northwestern Florida, western Georgia, Alabama, and Mississippi, with instructions to distribute the information widely. The storm then moved inland, the center passing almost directly over the city of Pensacola, Fla., at 10:30 a. m., 75th meridian time, when the barometer read 28.76 inches, with a wind of 48 miles an hour from the southeast and a tide 3 feet above normal height. At 10:12 a. m. the wind reached a 5-minute velocity of 114 miles an hour from the southeast, with an extreme velocity of 120 miles an hour from the southeast at 10:13 a. m., the anemometer going down at 10:14 a. m. After the lull attending the passage of the storm center the wind again increased from the west, reaching an estimated velocity of 120 miles an hour. After 11 a. m. the wind subsided to less than a gale.

Figure 1 is a reproduction of the automatic records of pressure, wind direction, and wind velocity at Pensacola during the passage of the storm.

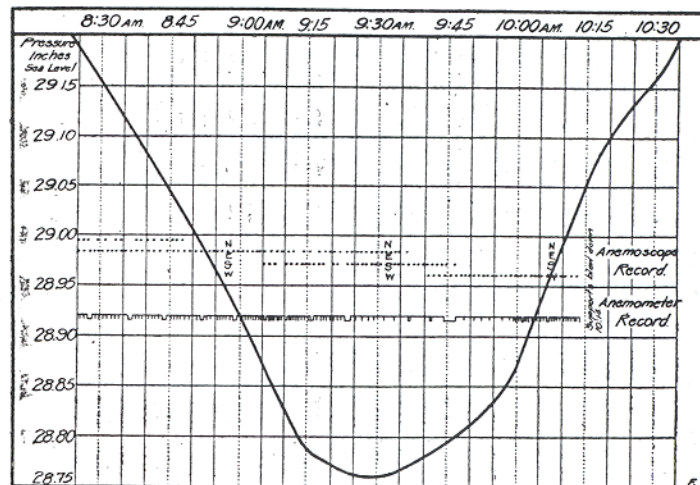


FIG. 1.—Graphs of pressure, wind direction, and wind velocity at Pensacola, Fla., during passage of hurricane of October 18, 1916. Anemoscope records dots at 1-minute intervals; anemometer records a tooth for every mile of wind, the pen is held down for the tenth mile.

At Mobile the lowest pressure was 29.22 inches at 8:35 a. m., 0.46 inch higher than at Pensacola. The wind velocity, however, was 115 miles an hour from the east at 8:25 a. m., practically the same velocity as at Pensacola, with an extreme velocity of 128 miles an hour from the east at 8:28 a. m., somewhat higher than at Pensacola.

Precipitation was not excessive in the vicinity of the storm center, but was torrential some distance away, both

to eastward and westward, Burrwood, La., reporting 11.88 inches during the 24 hours ending at 8 a. m., October 18. The storm center moved rapidly inland and the hurricane warnings were soon changed to storm northwest, the latter being lowered at 9 p. m.

The storm did little damage, comparatively speaking, as ample precautions had been taken on all sides, and furthermore, the storm moved so rapidly that its force in any one locality was soon spent. There was, however, one shipping casualty in the extreme western Caribbean with the loss of some 20 lives.

On the morning of October 15 the storm was central over Indiana, with a lowest reported pressure of 29.58 inches, and with marked high pressure and very steep gradients both to the northeastward and northwestward. Northeast and northwest warnings for strong winds and rain turning to snow were then ordered on the Upper Lakes, and southeast warnings for southerly gales on the Lower Lakes and on the Atlantic Coast from Hatteras to Eastport. Small craft warnings were also ordered from Wilmington, N. C., to Savannah, Ga. At 8 p. m., October 19, the disturbance covered the Upper Mississippi Valley and the Lake Region with indefinite formation, and with falling pressure to the northwestward. Warnings were therefore lowered from Cleveland, Ohio, westward, but were again hoisted on the following morning when the storm showed a remarkable redevelopment with a single center over extreme northeast Illinois, but as yet without strong winds. During the 19th southerly gales prevailed along the Middle Atlantic and New England coasts, and strong gales on the 20th over the Lower Lakes, with several casualties to shipping, attended by considerable loss of life. Over the Upper Lakes the winds were not so violent, and on the morning of the 21st the storm center had passed northeastward beyond the Province of Ontario.

Owing to the redevelopment of the storm, southwest warnings were again ordered at 3 p. m. of the 20th from Hatteras to Boston, and extended to Eastport at 10 p. m. Moderate southerly gales occurred as forecasted.

The subtropical disturbance of October 21, 1916.

On October 21 the pressure was again falling over the West Indies and the adjacent waters with a center of disturbance apparently in the vicinity of the western Bahamas. As the unsettled conditions persisted on the morning of the 23d, it was thought best to order northeast storm warnings from Fort Monroe, Va., to Charleston, S. C. As anticipated, the warnings were followed by fresh northerly gales that, however, did not quite extend to the coast stations. At 10 p. m., October 23, the warnings were extended to Jacksonville, radio reports indicating the necessity therefor. As there was little apparent change on the morning of the 24th, the northeast warnings were continued, as did also the gales, but by the morning of the 25th the winds had subsided, and the warnings were lowered.

Low pressure, however, persisted in Florida, the Antilles, and the Caribbean, and continued until the end of the month, necessitating frequent cautionary advices to shipping. While there was no definite center of disturbance located, moderate gales occurred at times over the western Caribbean.

HURRICANES OF 1916 AND NOTES ON HURRICANES OF 1912-1915.

By RICHARD HANSON WEIGHTMAN.

[Dated: Weather Bureau, Washington, D. C., Feb. 5, 1917.]

The season of tropical storms of the year of 1916 in the West Indies was noteworthy on account of the large number of disturbances reported. In fact in only 2 previous years out of the last 40 were more storms noted—namely, in 1886 and 1887. Besides the nine more important storms noted in 1916 there were several minor disturbances which, although locally severe, were of such short duration that it was not thought advisable to chart them. The season was also remarkable for the number of disturbances of intense character within the Tropics.

Detailed descriptions of the storms that occurred during the hurricane season of 1916 are given in the issues of the MONTHLY WEATHER REVIEW for the respective months and contain all data available at the time the several numbers went to press. Data which have come to hand since the issues above mentioned are presented in this paper and tend to supplement rather than to change the information previously published. Deductions presented regarding origin, track, and intensity that differ from those previously given are based on more complete data. There follows a list of the hurricanes of the past season arranged in chronological order with a few brief remarks accompanying them. An attempt is made to give a rough idea of the intensity of the disturbances noted by the use of the terms slight intensity, moderate intensity, of severe intensity, etc., while an estimate of their extent is indicated by employing expressions such as slight, moderate, large, etc. It must be realized, however, that reports in most cases are widely scattered and that estimates such as indicated above are in a number of cases therefore merely estimates. The paths of the 1916 hurricanes are shown grouped by months on Chart X (XLIV-152) of this issue of the REVIEW.

Remarks concerning the previous history of storms are based on a study of Bulletin "X", Hurricanes of the West Indies" by Oliver L. Fassig.

Appreciation is hereby noted of a collection of reports from a number of the islands of the West Indies forwarded by Mr. Francis Watts, commissioner of agriculture, Barbados, British West Indies, and also of numerous and valuable reports from vessels at sea.

NOTES ON HURRICANES OF 1916.

July 1-10.—The disturbance originated in approximately latitude 16° N., longitude 84° W., attained moderate intensity after passing through the Yucatan Channel, and reached the Gulf coast of the United States immediately west of Mobile, Ala., as a severe storm. The lowest barometer at Mobile was 28.92 inches and the maximum wind velocity (maintained for 5 minutes),

107 miles an hour from the east. Penascola reported a maximum velocity of 104 miles an hour from the south-east. These velocities were records for their respective stations. The velocity at Pensacola was exceeded in the storm of October 18, 1916, a report of which follows.

In a way this storm may be said to have followed an average course for the month, in that it passed to the east Gulf coast after having originated in the western Caribbean Sea.

July 11-15.—This disturbance, as far as reports are available, seems to have originated immediately east of the Bahamas in about latitude 24° $30'$ N. It moved northwestward to the South Carolina coast, passing inland over or near Charleston, S. C. The lowest pressure reading at that station was 29.02 inches and the maximum wind velocity 64 miles an hour from the northeast. The U. S. S. *Hector* in latitude 31° $45'$ N., longitude 78° $53'$ W., reported a barometer reading (aneroid) of 28.37 inches which, upon subsequent comparison of the instrument, is thought to be reasonably accurate. This disturbance was moderately severe in intensity and of small area.

This is the first July storm of record that passed northwestward from the region of the Bahamas and struck the south Atlantic coast.

July 12-22.—The origin of this storm was in about latitude 15° N., longitude 61° W. The center passed northwestward to latitude 29° and thence almost due north, striking the southern New England coast with diminished energy. The lowest pressure reading, 28.94 inches (aneroid), was reported in latitude 27° $30'$ N., longitude 73° W., by the S. S. *Ausable* shortly after 1 a. m. of the 19th, with wind force 11-12. This disturbance was of moderate to great intensity and of moderate to large area.

There is only one other storm of record in July that originated in low latitudes so far to the eastward. That storm passed westward south of the islands of the Greater Antilles, while the storm of the present year passed northwestward, north of the Antilles.

August 12-19.—This storm had its origin in approximately latitude 14° N., longitude 56° $30'$ W. It passed westward south of the Greater Antilles and through the Yucatan Channel, later striking the Texas coast a little south of Riviera, which is situated about 45 miles southwest by south of Corpus Christi. At Kingsville, about 14 miles north of Riviera, the lowest pressure reported was 28 inches (corrected) on an aneroid barometer, while at Del Rio, at 8 a. m. (75th meridian time) on the 19th, a pressure of 28.72 inches was observed. The highest wind velocity at Corpus Christi was about 90 miles an hour. The storm was severe and moderate to large in extent.

This disturbance followed an average course for the type of August hurricanes that passes through the Yucatan Channel.

August 22.—The disturbance passed south of Tortola (Virgin Islands) and across the island of Porto Rico on a course a little north of west, the lowest pressure reported at San Juan being 29.44 inches at 7 a. m., while the maximum wind velocity was over 90 miles an hour. The origin of this storm is very uncertain and, after crossing the island of Porto Rico, there is little if any trace of it to be found. It was of moderate intensity and extremely small area.

August 28-September 1.—The exact origin of the disturbance is unknown, but was undoubtedly some distance to the east of the island of Dominica. The first trace obtainable is at Roseau, Dominica, over or immediately south of which

city it passed about 7:30 p. m., of the 28th, with a minimum pressure reading at that station of 29.12 inches. It moved thence westward and passed immediately north of the island of Jamaica, with greatly decreased intensity, to a position to the northwest of Swan Island, in which vicinity it lost intensity. It was evidently of small diameter and great intensity while passing over Dominica.

September 4-5.—This disturbance originated east of the northern Bahamas and moved northwest, passing to the coast near and south of Jacksonville, Fla. It was of slight energy and extent.

September 20-23.—The origin of this storm was near Antigua, whence it passed northwestward as far as can be ascertained from a limited number of vessel reports and recurved to the west of the Bermudas. It was of only moderate extent and slight to moderate intensity.

October 4.—This disturbance had its origin northeast of the Bahamas, moved westward and passed inland over northern Florida. It was of small extent and energy.

October 7-12.—The origin of this disturbance is somewhat difficult to determine. Conditions were very unsettled, however, in the neighborhood of the Windward Islands during the 7th and 8th. On the afternoon of the 7th there were some indications of a disturbance near and slightly to the west of Martinique. On the 8th, Roseau, Dominica, experienced a heavy sea, the breakers washing high inland and causing some damage. On the evening of the same date the wind at Basseterre, St. Kitts, veered from northeast to southeast and held in that quarter all day. The sea was heavy and the waves came up over the sea wall. Reports from Tortola, Virgin Islands, indicate that during the morning and early afternoon of the 9th the winds held southeast and were light, but about 4 or 5 p. m., they increased in force. The wind was of greatest violence about 8 or 9 p. m. (100 miles an hour, estimated). After the passage of the storm the winds veered through south and southwest to west. The following readings of the barometer were taken by Mr. W. C. Fishlock, curator at Tortola, Virgin Islands:

October 9: 7 p. m., 29.70; 7:30 p. m., 29.40; 8 p. m., 29.10; 8:30 p. m., 28.90; 8:50 p. m., 28.80; 9:30 p. m., 28.94; 9:50 p. m., 29.10; 10:30 p. m., 29.20; 11 p. m., 29.30; 11:45 p. m., 29.30-29.40 (oscillating); midnight, 29.30-29.40 (oscillating).

October 10: 12:30 a. m., 29.30-29.40; 1 a. m., 29.40; 1:10 a. m., 29.40; 3 a. m., 29.58; 7 a. m., 29.74.

Readings made by Mr. Tanggard on the Island of St. Thomas and published in Lightbourn's Mail Notes, October 12, 1916, follow:

October 9: 7:30 a. m., 29.724; 1 p. m., 29.666; 2:15 p. m., 29.576; 3 p. m., 29.549; 5 p. m., 29.439; 6 p. m., 29.260; 7 p. m., 28.263; 9 p. m., 28.264; midnight, 29.261;

October 10: 6 a. m., 29.637; 8 a. m., 29.700.

The lowest reading at St. Croix, as reported in the Barbados Standard of October 12, was 28.45 inches during the night of the 9th-10th. At St. Thomas and Tortola the winds veered, while at St. Croix they backed. The disturbance evidently passed nearly over and a little to the south of St. Thomas, on a course almost due northwest and later recurved to the northeastward south of the Bermudas, evidenced by a report of hurricane winds encountered by the bark *Bellas* in latitude 27° 40' N., longitude 62° 20' W., and by a report from the *Aros Castle* (Br. SS.) in latitude 25° 18' N., longitude 63° 13' W. According to this report the *Aros Castle* experienced shifting southwesterly winds of hurricane force, with a barometer reading of 28.38 inches (aneroid) at 4 p. m. of the 11th. From earlier observations by the same vessel it is estimated that the aneroid read between 0.10 and

0.20 inch too low. The storm was of small area and of great intensity.

October 12-18.—The origin of this disturbance is somewhat doubtful, although the first definite indications place it to the south of Jamaica in approximately latitude 16° N., longitude 77° W., on the 12th. It then moved to the westward, passing south of and very close to Swan Island, where a barometric pressure of 28.94 inches was reported during the 14th, with winds of hurricane force. Several reports from vessels enable the storm to be quite closely located on the 16th and 17th and show that the disturbance, after moving a little north of west during the 15th, turned sharply to the northward on the 16th and reached the Gulf coast on the 18th, very close to and immediately west of Pensacola, Fla., where a barometer reading of 28.76 inches was reported. The maximum wind velocity, reported as 114 miles an hour, constitutes a record for the station. The storm was very intense and of moderate area.

This storm was quite remarkable for the month in that it held a westerly course in low latitudes for four days, finally reaching longitude 87° or 88° W., before turning to the northward.

November 12-15.—This disturbance originated in approximately latitude 12° N., longitude 81° W. It moved thence northwestward, recurving over the southeastern portion of the Gulf of Mexico, and advanced rapidly east-northeastward over extreme southern Florida during the 15th in the trough of a disturbance to the northward. This disturbance was evidently of marked intensity in lower latitudes, for according to press reports considerable damage was caused to property along the coast of Spanish Honduras and in Yucatan.

NOTES ON HURRICANES OF 1912-1915.

Chart X (XLIV-121), in the MONTHLY WEATHER REVIEW for September, 1916, shows the tracks of tropical storms for the period, 1912-1915. A few notes, arranged by months, follow regarding these storms.

August 10-17, 1915.—This disturbance originated slightly to the east of the island of Martinique and passed, on a course a little north of west, south of the Greater Antilles, along the northern side of the island of Jamaica. Its course then bore slightly more to the northward, and, after passing nearly over Cape San Antonio, Cuba, it advanced northwestward to the Texas coast immediately south of Galveston. The lowest pressure reading was 28.20 inches at Houston, Tex., up to this time the lowest mercurial barometer reading reported in the United States. (Record was again broken in the September, 1915, storm at New Orleans.) This storm was of hurricane intensity while in the Caribbean Sea, before passing through the Yucatan Channel, as indicated by the destruction of the wireless tower and other equipment at Cape San Antonio. The storm was of great magnitude.

The track of this disturbance was not abnormal for August storms that pass through the Yucatan Channel. In this connection, it is interesting to note that all previous August storms that have passed through the Yucatan Channel have advanced without recurve to the Texas or Mexican coasts, no storm of this character ever having struck the Gulf coast east of Galveston.

August 29-September 9, 1915.—As nearly as can be ascertained, this disturbance had its origin in a proximity latitude 27° N. and longitude 27° W. It moved first on a course slightly north of west, passing to a position northwest of the Bermudas, whence it passed southward to the west of the Islands, then southeastward, then

westward and later northward and northeastward. From the evening of the 2d to the evening of the 4th the pressure at Hamilton ranged between 29.17 and 29.32 inches.

The track of this storm was most unusual, its recurve being blocked and the storm forced southward by the high pressure to the northward. The storm was moderately severe and of moderate area.

September 1-4, 1915.—This disturbance originated in approximately latitude 16° N., longitude 80° W., and after passing north-northwestward over western Cuba, crossed the Gulf coast immediately west of Apalachicola. The lowest pressure recorded at that station was 29.32 inches. A pressure of 29.08 inches, however, was reported by the United States Coast Guard cutter *Miami* off the west coast of extreme southern Florida on the morning of the 3d. The intensity of this storm was moderately severe and its diameter extremely small.

September 22-30, 1915.—This storm had its origin to the west of the Windward Islands in approximately latitude $14^{\circ} 30'$ N., and longitude 63° W. It moved westward, passing south of Jamaica and thence northwest through the Yucatan Channel, crossing the Gulf coast slightly west of New Orleans. The lowest pressure recorded at that station was 28.11 inches, which is probably the lowest reading of a mercurial barometer ever observed

in the United States. The report of lowest pressure observed at sea was given by the S. S. *Almirante*, in approximately latitude $15^{\circ} 50'$ N., and longitude $77^{\circ} 30'$ W. The report contained information as follows: "Barometer pumping between 27.50 and 27.60 inches." The barometer was an aneroid with a correction of plus 0.01 inch. This is the lowest authentic reading reported in the West Indies or Caribbean Sea so far as known.

The hurricane was the most intense in history so far as our records show and was of large area. The track was not unusual for a storm of this month that passes from the Caribbean Sea through the Yucatan Channel.

October 11-17, 1912.—This disturbance originated a short distance west of Jamaica in approximately latitude 18° N., longitude 80° W., and, after passing west-northwestward through the Yucatan Channel, struck the Texas coast at a point about equally distant from Corpus Christi and Brownsville. The disturbance was of only moderate intensity and of small to moderate area.

The course of this disturbance was most unusual when compared to other October storms that passed through the Yucatan Channel. Only one previous storm of record followed a track at all similar to the 1912 storm, namely, that of 1887. The storms of 1886, 1887, and 1912 are the only tropical storms in the month of October that have struck the Gulf coast west of Mobile.