Gall described and figured all three of his projections in a paper [6] wherein he states:

* * * for more than 20 years after I had exhibited the three new projections before the British association I was the only person that used them. * * *

The first to adopt it [Gall's stereographic projection] was the late lamented Mr. Keith Johnston, who introduced it into his miniature atlas, which was, I believe, the first of his publications. The next to adopt it were Messrs. Chambers and Mr. Bartholomew, who has done more than any other to make it known. After them it was adopted by Messrs. Nelson, Gall and Inglis, and Mr. Heywood, of Manchester.

Gall invites the free use of his projections, asking only that "when they are used, my name may be associated with them, and that they may be severally distinguished as Gall's stereographic, isographic, and orthographic projections of the world." Gall's (stereographic) projection was used, and credited to its originator, for the chart of winds and storms in Keith Johnston's series of atlases of physical geography; and it is described, with the statement that "this is the first published map in which this projection has been used", in the *Hand Book of Physical Geography* (Edinburgh and London, 1870) written to accompany these atlases, pages 162–163. The chart is here reproduced as figure 3.

The subsequent widespread dissemination of the projection through meteorological literature appears to have arisen from its adoption in several classic publications issued at Edinburgh, especially the monographs by Alexander Buchan. Buchan's famous *Handy Book of Meteorology* (Edinburgh and London; first edition 1867, second edition 1868) contains world charts of isobars and isotherms on the Mercator projection; but his *Introductory Text-Book of Meteorology* (Edinburgh and London, 1871) employs Gall's projection, though without designation and with no indication of the reasons for its adoption. Buchan also used this projection in his first study of the distribution of pressure and winds over the globe,[7] again without giving the name of the projection; and finally, he employed it in the great Challenger Report,[8] on page v of which occurs a statement that the report contains 52 newly constructed maps, of which "26 shew the mean monthly and annual temperature on hypsobathymetric maps, first on Gall's projection, and second on north circumpolar maps on equal surface projection; and 26 shew, for each month and for the year, the mean pressure of the atmosphere and the winds" also on Gall's projection.

Buchan's great work remains a classic and standard source of information even today. Previous to the Challenger expedition, available observations of the meteorological elements were almost entirely restricted to land; and the only comprehensive investigations on the distribution of the elements over the globe were those of Dove on temperature,[9] the previous memoir by Buchan on pressure and winds, and that of Coffin on winds,[10] all necessarily based on incomplete and more or less defective data. Buchan undertook a rediscussion of all the available information, with special reference to the Challenger observations. His revision of the world maps of pressure, temperature, and winds attained a degree of completeness and homogeneity not previously reached; and nothing comparable has since been achieved for the globe as a whole with the further data now available.[11]

Buchan edited the *Atlas of Meteorology* that forms Vol. III of Bartholomew's Physical Atlas, and the world maps in this atlas are on Gall's projection. The projection frequently appears in many modern atlases, particularly those by Bartholomew, but usually without a designation, though the other projections used are often labeled. Buchan's world meteorological charts have been widely copied; and thus the projection has found its way into numerous standard meteorological texts and reference books, e. g., Davis' Elementary Meteorology; Milham's Meteorology; Humphreys' Physics of the Air; and many other publications. The distributions of pressure and temperature over the world are to a marked extent latitudinal, hence an increase in the longitudinal scale of a map in high latitudes is not so important as a latitudinal effect; in this respect, Gall's projection is better than Mercator's, because the rapidly increasing scale of the latter in high latitudes leads to an excessive separation of the isotherms and isobars toward the poles.

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TROPICAL DISTURBANCES, SEPTEMBER 1936

By I. R. TANNEHILL

[Marine Division, Weather Bureau, Washington, October 1936]

Six tropical disturbances were charted during September in the North Atlantic Ocean and Gulf of Mexico, and three in the southeastern North Pacific Ocean near the coast of Mexico. Three of the six disturbances on the Atlantic side were of full hurricane intensity; one was of only moderate force; the other two were of minor character. Accounts of the Pacific disturbances are contained in this REVIEW under the heading "North Pacific Ocean."

August 28–September 5.—The first indications of this disturbance were contained in radio reports from ships in the vicinity of 15° N., 45° W. on August 28. According to a report received by mail, the S. S. *Van Rensselaer* at about 9 a. m. (ship's time) on that date at 16°14′ N., 43°14′ W., had wind WSW., 5, with barometer reading 29.67 inches (corrected); at 4 p. m. the highest wind, SSE. 10, was experienced on this ship at about 17½° N., 42° W.

After August 28, observations were lacking in the vicinity of the disturbance until the evening of August 31, when ship reports definitely placed the center of a vigorous cyclone near 25° N., 56° W. It is not possible with available reports to locate the center of the disturbance prior to August 31. However, observations at 7 a. m. (eastern standard time) on the 28th were received by radio from the S. S. *Robin Gray* at 10.3° N., 44.7° W., and from the S. S. *Western Queen* at 12.5° N., 46° W., also at 7 p. m. (eastern standard time) from the S. S. *Van Rensselaer*, which was then at 17.5° N., 41.3° W., wind SE. 5, with indications that a tropical storm had formed. This is the farthest area to the eastward in the Atlantic in which the existence of a tropical disturbance has been revealed by radio reports to the Weather Bureau. The previous record was the location of a disturbance on the morning

of September 10, 1928, by a radio report from the S. S. *Commack* in 17° N., 48°15′ W.[1]

By September 1 the disturbance had attained full hurricane intensity. The S. S. *Pan America* reported its lowest barometer reading, 29.01, at 1 p. m., ship's time, at 27°14′ N., 58°08′ W., with wind NW., force 11, increasing to NW. 12 at 2 p. m.

On September 2, the hurricane recurved to the eastward of Bermuda with center in longitude 58° W. Between 2 and 3 a. m., ship's time, on September 3, the S. S. *West Lashaway* at 35°22′ N., 54°14′ W., had full hurricane winds, ESE., barometer 28.71. Reports indicate that full hurricane intensity was maintained until the morning of the 5th near 42° N., 39° W., where the S. S. *Nike* experienced wind WSW., force 10, barometer 28.32.

September 7–8.—At 7 a. m. eastern standard time, September 7, the S. S. *Chesapeake* at 20°17′ N., 58°56′ W., with wind SW. by S., barometer 29.77 (uncorrected) reported that there were indications of a tropical disturbance forming to the northward. Other observations from the vicinity at that hour placed the center at about 21° N., 59° W. Twelve hours later there was a mild cyclonic wind circulation over the Leeward Islands and the ocean to the northward, with center near 21° N., 62° W. By the morning of the 8th, the disturbance, which continued to be of minor intensity, appeared to have advanced toward the west-northwestward, but later observations failed to reveal any definite wind circulation.

September 8–26.—While the preceding disturbance was dissipating near the Leeward Islands on the 8th, there were signs of another disturbance to the eastward with center in the vicinity of 13° N., 50° W., at 7 p. m., eastern standard time, of the 8th. At that time the S. S. *West Selene* was at 13.3° N., 52.1° W., and a long swell from the northeast was observed. The swell became heavier late on the 9th and on the 10th, with slowly falling barometer, when the vessel was about 250 miles east of the Leeward Islands. The observing officers estimated the distance to the disturbance to be about 100 miles.

Reports from other vessels on the 10th indicated the presence of a well-developed cyclone centered at approximately 18° N., 55° W. During the following week, it moved steadily northwestward and approached the North Carolina coast on the 17th. Its progressive movement was very slow at first but increased to about 10 miles an hour as it approached Hatteras.

By the morning of September 15 the hurricane was of wide extent and marked intensity. On the 16th the area of winds of force 6 and higher (Beaufort scale) was about 1,000 miles in diameter. By that criterion it was one of the largest tropical cyclones of record.

As the hurricane center approached Hatteras it began recurving to northward and, after passing a short distance east of the Virginia Capes on the 18th, it turned northeastward at an increasing progressive rate. The storm maintained its identity until the 26th at about 45° N., 30° W. The entire track is shown on chart XI.

A considerable number of ships were heavily involved in or very near the hurricane center. A digest of the wind and barometric observations of several of them is contained in the table of "Ocean gales and storms" elsewhere in the REVIEW. One in particular, the S. S. *El Occidente*, in 35°10′ N., 74°50′ W., at 5 a. m. (ship's time) of the 18th had lowest barometer 28.60 inches, and reported light fog during the lull at the center about 6 a. m.

In the vicinity of Hatteras, the hurricane was one of the most severe of record. The maximum wind velocity was 80 miles an hour from the northwest (corrected). A report from the official in charge of the Weather Bureau office at Hatteras includes the following:

> There was no loss of life on the entire island, but considerable damage to property: Homes, fishing equipment, wharves, fish houses, ice houses, and many other small buildings all along the water front on the sound shore. From the island of Ocracoke, 20 miles south of Hatteras, where damage was only light, on up the North Carolina coast to the Virginia line, it is estimated that approximately $20,000 damage was done. This damage could not be avoided, because timely warning was given to all. Everyone took extra precaution to safeguard their property so far as possible, but there was nothing else that could be done. It is simply impossible to even imagine just what would have been the results, even in the loss of life, had it not been for the timely warnings given the entire public.

The Section Director of the Weather Bureau at Raleigh estimated the storm damage in North Carolina to roads and bridges, $25,000; to homes, fishing equipment, wharves, and fish houses, $30,000.

At Cape Henry the full force of the hurricane winds was not recorded; the anemometer cups and spindle were carried away by the wind at 11:37 a. m. (eastern standard time) of the 18th; one cup had previously been blown away. The wind was estimated at 75 miles an hour.

Conditions in the Virginia coastal area are summarized in the following excerpt from the report of the official in charge of the Norfolk Weather Bureau office:

> The tropical hurricane that visited the Tidewater area on September 17, on its journey up the coast, can be characterized as the worst storm ever experienced in this section, and only the intensive system of warnings by the Weather Bureau, and the splendid cooperation of the general public, as well as municipal, State, and national forces, saved it from being a major catastrophe.
>
> Every available facility and means for warning the public was utilized, the radio, the newspapers, Coast Guard communication circuits, and municipal protective agencies, resulting in preparedness on such a scale as was never before witnessed here.
>
> That the results fully justified the extensive preparations is evidenced by the comparative slight property loss suffered, estimated at not more than $200,000 in the city proper, and not more than $500,000 in the Norfolk area, while only two fatalities occurred in this section. Those were caused indirectly by the storm; W. T. Butt, 59 years of age, resident of Princess Anne, dying as the result of injuries suffered when struck on the head by flying debris, and Udell George, Negro, 23 years of age, was drowned in the southern branch of the Elizabeth River in an effort to recover a rowboat blown adrift.

Moving northeastward from the Virginia Capes, the hurricane center continued at sea, but gales were felt along the coast. At Nantucket the lowest barometer reading was 29.27 inches at about 5 a. m. of the 19th with maximum wind velocity 45 miles (extreme 58) at 7:40 a. m., eastern standard time.

Timely advices and warnings were disseminated at frequent intervals from Jacksonville and Washington as conditions justified. Northeast storm warnings were ordered by the Washington forecaster at 10:30 p. m., eastern standard time, on September 16, for the coastal region from Beaufort, N. C., to the Virginia Capes. Northwest storm warnings were ordered by the Jacksonville forecaster for the North Carolina coast south of Beaufort at 2:45 a. m. of September 17. At 10 a. m. of the 17th, hurricane warnings were ordered north of Beaufort to Manteo; and at noon from Beaufort southward to Wilmington. At 3:30 p. m. northeast storm warnings were extended to Atlantic City. At 9:30 a. m. of the 18th, displays were changed to whole gale warnings north of Virginia Capes to Sandy Hook. Whole gale warnings were ordered at 4 p. m. from New Haven to Provincetown; and northeast storm warnings were displayed elsewhere north of Sandy Hook.

[1] MONTHLY WEATHER REVIEW, 1928, p. 347.

September 11–13.—Of only moderate intensity, this disturbance was first located by radio reports from the S. S. *Turpam* in 22° N., 93° W., at 1 p. m., eastern standard time, on the 11th, wind ESE., force 7, barometer 29.80, and indications that a tropical storm had formed. The S. S. *Nemaha*, at 26° N., 95° W., reported that the highest wind experienced was southeast, force 8, with lowest barometer 29.77 at 3 a. m. eastern standard time, September 13. Without evidence of increase in intensity, the disturbance moved in a general northwest direction and crossed the Texas coast near Brownsville on the 13th.

The report of Forecaster Dyke at New Orleans included the following:

The disturbance moved slowly northwestward until the evening of the 12th, when it turned to the right and moved rapidly north-northwestward, passing very close to and east of Brownsville, Tex., on the morning of the 13th, moving at the average rate of approximately 16 miles an hour from 7 a. m. of the 12th to 8 a. m. of the 13th. There was apparently little variation in intensity, as reported wind velocity and barometric pressure while the disturbance was over water and when it reached shore were about the same. Thereafter it passed inland to the west of Corpus Christi, Tex. Easterly winds of force 7 prevailed on Padre Island at Brazos Santiago Pass, 23 miles northeast of Brownsville; and westerly wind of 27 miles an hour was recorded at Brownsville at 7:48 a. m., eastern standard time, showing that the center of the disturbance, probably without a calm or lull, passed between Brownsville and Brazos Santiago Pass. A maximum wind velocity of 35 miles an hour was recorded at Corpus Christi at 12:30 p. m., eastern standard time. A wind of 30 miles an hour from the southeast occurred at Galveston before 8 a. m. The lowest pressure reported was 29.54 at Brownsville at 7 a. m., eastern standard time. Tide-gage readings on the Texas coast were not much above normal.

On indications of the 8 p. m. map of the 12th, northeast storm warnings were ordered from Brownsville to Corpus Christi. Previously in the afternoon a bulletin was sent to Galveston, Corpus Christi, and Brownsville, advising that persons on exposed islands and in boats off Texas coast from Matagorda Bay to Port Isabel should return to the mainland for the week end, due to possibility of storm increasing in intensity and curving so as to move farther north. Fortunately an increase in intensity did not occur and it became unnecessary to use United States Coast Guard planes which were sent to the Texas coast during the night but were not used for warning purposes. Persons who evacuated the islands and found shelter escaped the driving rains attending the storm.

Storm warnings were extended at night and morning of the 13th over the remainder of the Texas coast.

September 19–24.—Reports from the Leeward Islands and vessels to the northward gave some evidence of cyclone formation at about 21° N., 63½° W., at 7 a. m. of September 19. Somewhat more definite cyclonic circulation was apparently centered at about 24° N., 67½° W., at 7 a. m. of the 20th, with northwestward movement. During the 21st, very rapid development took place with recurve to the north-northeastward. As a fully developed hurricane of small diameter, it was centered close to 29° N., 70° W., at noon on the 22d.

The S. S. *Saramacca* passed through the center of the disturbance on the 22d at 28°55′ N., 69°45′ W., with lowest barometer 28.86 at noon, ship's time, and wind SSW., 12.

Near the point of recurve the hurricane moved slowly but its progressive speed increased on the 23d; and by 7 p. m. of the 24th it was approaching Nova Scotia. During the night it merged with another disturbance approaching from the westward.

September 25–October 1.—This disturbance appears to have been of minor character at all stages. Its beginnings are not clearly shown in the observations at hand. As a weak depression it moved west-northwestward across Florida on the 27th and early on the 28th, then northwestward across the extreme northeastern Gulf, and inland at Apalachicola. From the report of Forecaster Dunn at Jacksonville:

A maximum wind velocity of 26 miles from the south occurred at Tampa. * * * Tarpon Springs reported an estimated velocity of 35 miles. This storm did not give any strong winds at Apalachicola although a barometer reading of about 29.70 inches occurred early on the 29th. Except for notice of squalls in the East Gulf marine forecast, no warnings were issued in connection with this disturbance.

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[RICHMOND T. ZOCH, *in Charge of Library*]

By AMY D. PUTNAM

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