trace to 8.10 inches. Such fluctuations mean that the rainfall is not dependable for ordinary types of agriculture. Under natural conditions the Rogue River Valley would be an area of agricultural risk. With this variability of rainfall, together with a low average total and an unfavorable seasonal distribution, it is easy to see why the agricultural specialization of the valley has awaited the development of irrigation.

A third type of rainfall variability may also be demonstrated from the Ashland records. Examination of the yearly precipitation curve since 1879, and the fragmentary private record from 1854 to 1865, shows considerable oscillation. It is also noticeable that these oscillations rise to definite crests. One such crest seems to be indicated around 1864, another between 1880 and 1885, and still another from 1905 to 1910. The average time lapse between these peaks is roughly 22 or 23 years. Apparently this represents a rough pulsation of rainfall. Climatologists are inclined to discredit claims of fixed and definitely recurring climatic cycles, but a pulsatory tendency is frequently evident. While these pulsations do not occur with mathematical frequency, they may form the basis for a certain amount of prediction or expectation. It is evident that a drought period reached its trough about 1930. Since 1930 the trend has been somewhat upward, with slight drops in 1933 and 1935 as is to be expected because of the high annual oscillation characteristic of the valley. During the past two decades, 14 years have been definitely below the mean and only 2 have been definitely above. Hence it may perhaps be expected that the next 5 to 10 years will average an inch or two more rainfall than the last 10 years have. As it stands now, the mean for the official 44-year record for Ashland ending in 1922, and contained in the old section 17 of the Summary of Climatological Data for the United States, is indicated as 20.35. In 1935 that mean stood lowered to 19.75 inches of rain.

If such an increase occurs, it may aid in bringing on generally improved economic conditions for the valley, as it was probably no accident of history that the upswing of the last rainfall crest, 1905 to 1910, saw the greatest increase in population in the history of the valley. This will not mean that irrigation will be less depended upon, as extreme oscillations in annual amount are likely still to take place during a series of heavier rainfall years. The greatest benefit will accrue through a lessened cost for irrigation water on an average, an increase in good pasture land and a restoration of ground-water supplies both for dry and subirrigated farming in the lowlands and in the natural water-storage reservoirs in the uplands.

How may these precipitation variations be accounted for? It would appear that they are closely related to migrations of the prevailing paths of cyclonic and anticyclonic storms. The winter cyclonic path ordinarily passes just north of the Rogue River region. However, cyclonic and anticyclonic storms seldom follow one another in identical paths. Oscillation is much more characteristic of their behavior. In plains areas it is probable that deviations may make little difference; but in a narrow valley embedded 2,000 to 3,000 feet below the surrounding country, the very hearts of these storms must pass through, or else the meteorological effect may be almost entirely nullified, as there are mountain barriers casting a rain shadow from any direction.

GALL'S PROJECTION FOR WORLD MAPS

By I. R. TANNEHILL and EDGAR W. WOOLARD

[Weather Bureau, Washington, September 1936]

The properties of the projection on which any given map is constructed are often of considerable interest and importance in connection with the purposes for which the map is to be used; it is always desirable, and in many cases essential, that these properties be known. Hence the particular projection that has been employed should be specifically stated on the map, as it may be difficult or impossible of identification with certainty from mere inspection. It is a somewhat curious fact that one of the most widely used of map projections, particularly in meteorology, and the one that has long been the principal world base used by the United States Weather Bureau—viz, Gall's projection for world maps, figure 1—has seldom been thus explicitly designated, and must often have been mistaken for Mercator's projection, figure 2, to which it is superficially very similar.

Gall's projection was devised by the Reverend James Gall, of Edinburgh, and first presented by him in 1855, before the British Association for the Advancement of Science. It has received little recognition in formal treatises on map projections, probably for reasons indicated by the following comments of Deetz and Adams, who mention the projection but do not describe or figure it: [1]

> Two projections of the sphere that are found in some atlases, as giving a fair representation of the world, are the Van der Grinten projection and Gall's projection. These two projections are neither conformal nor equal-area and may be classed as intermediates, having no properties of definite scientific value. They present a fair uniformity in the configuration of the world, avoiding the excessive scale increments of the Mercator in the higher latitudes and lessening the distortions of equal-area projections. Their utility nevertheless is pictorial and their practical importance is limited.

A satisfactory cartographic representation of the entire globe presents even greater difficulties than that of only a more or less limited portion of the earth's surface; and it cannot be expected that any one projection can be found which will adequately serve all purposes. The choice of a projection must depend in each case on the particular needs at hand. A cylindrical projection has many advantages for world maps, and this fact has led to an extensive use of the Mercator projection for world maps for all purposes; this projection, however, was designed primarily for use in navigation, and although it is so perfectly adapted to nautical needs as to be *indispensable* to the mariner, it has notable defects for many general purposes, even though it can never be entirely displaced by any other projections.[2]

Gall was led to devise his projection while constructing maps of the constellations for a celestial atlas. In his own words: [3]

> Having occasion to publish an "Atlas of the Stars", I was anxious to produce a panoramic view of the equatorial heavens, extending as far northward as possible; and my object was, of course, to conserve the appearance of the constellations both in regard to form and comparative area. I first attempted Mercator's projection, but the result was not satisfactory: the orientation, indeed, was perfect, but everything else was sacrificed. It then occurred to me that if, instead of rectifying the latitude to the longitude through-

[1] C. H. Deetz and O. S. Adams, Elements of Map Projection, U. S. Coast and Geodetic Survey, Sp. Pub. 68, 4 ed., p. 182. Washington, 1934.

[2] *Cf.* Deetz and Adams, *op. cit.*, pp. 146-147, 101-104, and 34-35.

[3] James Gall: On a new projection for a map of the world, Proc. Roy. Geographical Soc., 15: 159, 1870. This paper includes a plate showing the projection.

out, we rectified it only at the forty-fifth degree, we might adopt the stereographic latitudes up to the sixtieth degree without any distortion.

It then occurred to me that the same projection would be applicable to a cylindrical map of the world, and would be a great improvement on Mercator, by extending the stereographic latitudes to the pole. I drew a map on the new projection, and being satisfied with the result, I read a paper before the British Association in Glasgow, in 1855.

Since that time I have greatly improved it by adding polar supplements of the same projection for the Arctic and Antarctic regions; and on showing it to some of my publishing friends in Edinburgh, am pleased to find that it has received their approval, and been adopted, instead of Mercator, for their publications.

In his paper before the British Association, Gall states: [4]

Cylindrical maps alone can represent the whole world in one diagram. There are only three features in which a cylindrical map can be accurate: (1) in orientation; (2) polar distance; and (3) proportion of area; but if one of these be obtained, the others must be sacrificed. The best projection is that which will divide the errors, and combine the advantages of each. Mercator's projection sacrifices form, polar distance, and proportionate area, to obtain accurate orientation for the navigator; whereas to the geographer, form, polar distance, and proportion of area are more important than orientation.

Polar distance is obtained by making the degrees of latitude equal.

Proportion of area is obtained by projecting the degrees of latitude orthographically.

In these two projections orientation can be correct at only one line of latitude; but if we select the forty-fifth degree of latitude, and make the orientation correct at that line, the error is halved on each side and the distortion less offensive.

The projection which unites all the advantages of the three, in the best proportion, is obtained by projecting the degrees of latitude stereographically, and selecting the forty-fifth degree of latitude as the line of correct orientation.

[4] James Gall: On improved monographic projections of the world, Rept. twenty-fifth meeting Brit. Assoc. Adv. Sci. at Glasgow, 1855, p. 148. London, 1856.

Gall exhibited to the British Association three new cylindrical projections suggested by the preceding remarks. Any projection on a cylinder tangent at the equator gives a map in which the meridians and parallels form two mutually perpendicular systems of parallel straight lines; the meridians are equally spaced, but the spacing of the parallels depends on the method of projection and determines the properties of the map. As indicated in the above quotations, the Mercator projection limits the north-south stretching with increasing latitude to equality with the east-west stretching; the map is conformal, and the scale is the same along the meridian and the parallel through a point. It is the only projection on which a line of constant bearing is a straight line. The distortion of the shapes of large areas is not great except in very high latitudes, but the large variation in the scale with latitude leads to excessive exaggeration of areas with increasing latitude. An equal-area map will be obtained by projecting the parallels orthographically, but violent distortions of shape are then produced in higher latitudes. A map with any other spacing of the parallels will be neither conformal nor equal-area, but may nevertheless possess characteristics which for some purposes outweigh these properties, and which are lacking in the preceding projections.

In particular, an equal spacing of the parallels lessens the distortion produced by the orthographic spacing, especially if the spacing of the parallels is made greater than that of the meridians in some appropriate ratio; and in one of the three projections proposed by Gall, the parallels are equally spaced in such a way that the latitude is rectified at the 45th parallel, giving a so-called "modified

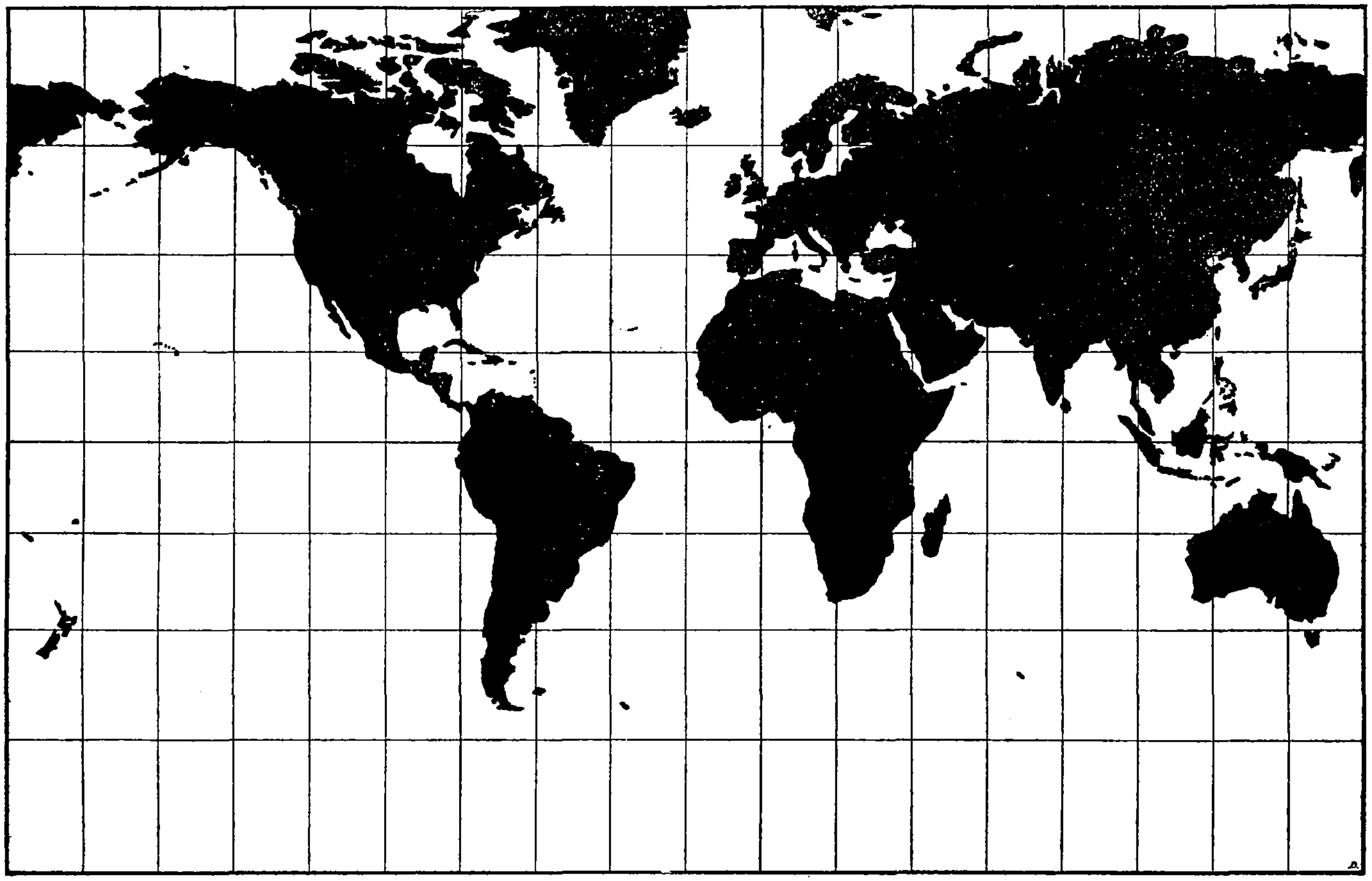

FIGURE 1.—Chart of the world on Gall's projection.

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cylindrical equal-spaced projection" with the spacings of the meridians and the parallels in the ratio of about 7 to 10;[5] this construction constitutes Gall's Isographic Projection, which Gall considered to be of value for many physical maps, especially meteorological and hydrographic. Another of the projections proposed by Gall is one in which the latitudes are projected orthographically, but are rectified at the forty-fifth parallel instead of at the equator as in the ordinary orthographic cylindrical projection; this is Gall's Orthographic Projection, which is equal-area and is valuable for some physical maps, especially statistical ones, but in which the geographic features are considerably distorted.

The most generally useful of the projections devised by Gall, however, and the one referred to simply as Gall's projection, is his stereograhic projection; it is not mathematically exact in conformality, polar distance, or comparative area, but it more nearly approaches having all three properties at once than the others, and conserves geographic features better. As compared with the Mercator projection, Gall claims as its advantages that it gives a more accurate representation of geographic forms, it is capable of representing the entire globe including the poles, it represents polar distance and relative area more accurately, and it saves 25 percent of the space occupied by the Mercator map.

Gall's stereographic projection is constructed by projecting the latitudes stereographically—that is, perspectively from the point on the equator diametrically opposite the point of tangency of the cylinder—and then spacing the meridians so as to rectify the longitudinal and latitudinal scales at the 45th parallel; if r be the radius of the earth and a the length by which it is represented in the construction, then a latitudinal arc $rd\varphi$ of the earth's surface maps into a linear distance $d\left(2a \tan \frac{\varphi}{2}\right)$ on a tangent cylinder; the north-south scale at latitude φ is therefore $\frac{a}{r} \sec^2 \frac{\varphi}{2}$, whence to equalize the longitudinal and latitudinal scales at that latitude the complete parallel (of length $2\pi r \sin\varphi$) must be represented on the map by a line of length $(2\pi r \sin\varphi)\left(\frac{a}{r} \sec^2 \frac{\varphi}{2}\right) = 4\pi a \tan \frac{\varphi}{2}$. The projection may be distinguished by inspection from that of Mercator by noting the shapes of Greenland and Alaska.

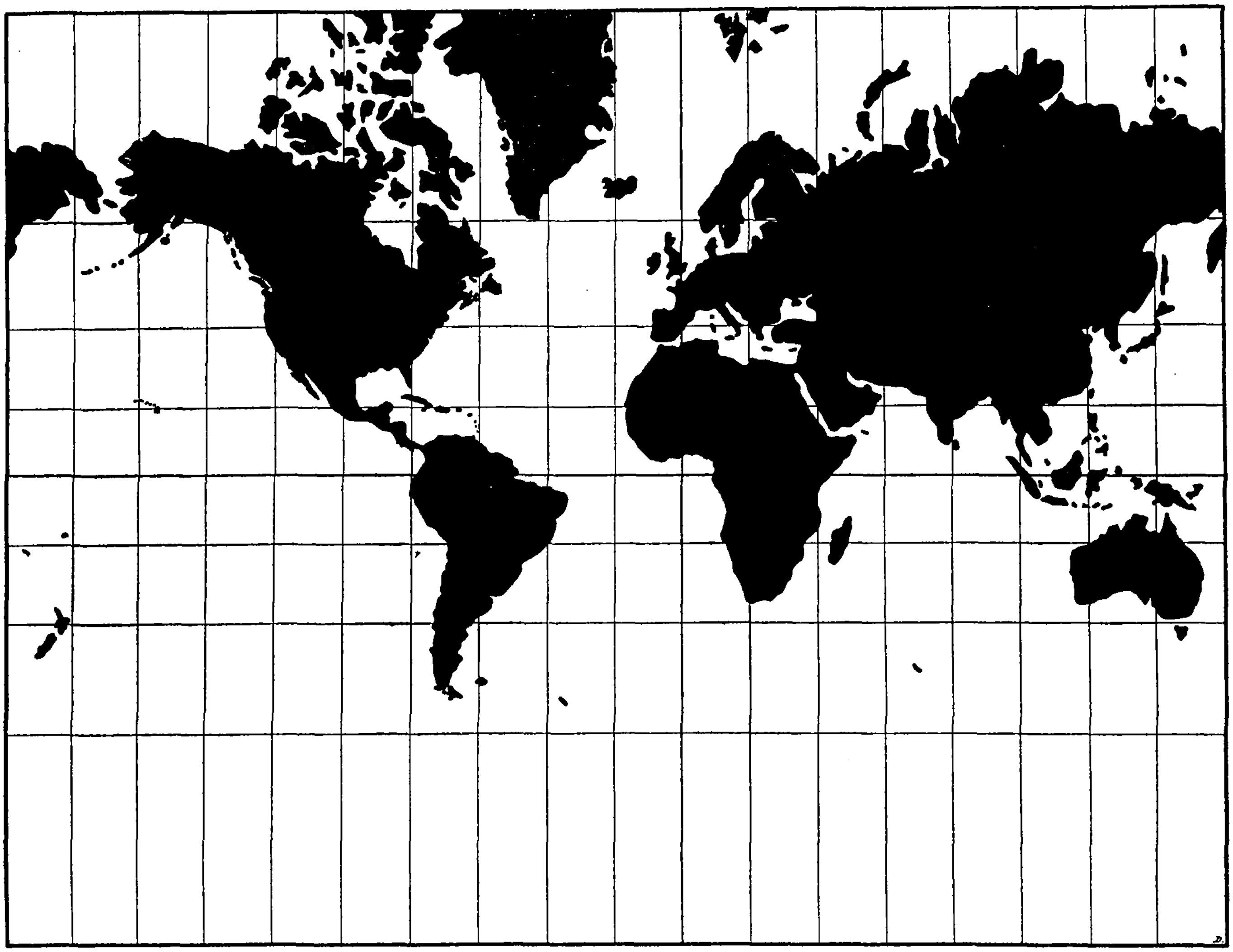

FIGURE 2.—Chart of the world on Mercator's projection.

[5] The length of the parallel of 45° is 0.70711 (=sin 45°) that of the equator; hence if the scale along the forty-fifth parallel is to be the same as that along a meridian at latitude 45°, a given arc of longitude will occupy only 0.70711 the linear space occupied by an equal arc of latitude, i. e., the spacings of meridians and parallels must be in the ratio 0.70711.

FIGURE 3.—The first published map on Gall's projection.

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.

[6] Rev. James Gall. Use of cylindrical projections for geographical, astronomical, and scientific purposes. Scottish Geographical Magazine, 1:119–123, 1885.

[7] Alexander Buchan: The mean pressure of the atmosphere and the prevailing winds over the globe, for the months and for the year. Pt. II. Trans. Roy. Soc. Edinb., 25:575–637, 1869. The charts were engraved by W. and A. K. Johnston. On p. 577 is the statement that the data were entered on polar and Mercator projections and then "ultimately transferred to charts of the projection on plates XXV to XXVII."

[8] Report on the scientific results of the voyage of H. M. S. *Challenger* during the years 1873–76. Physics and Chemistry, vol. II, pt. V. Report on atmospheric circulation. By Alexander Buchan. London, 1889. The charts were engraved by Bartholomew.

[9] H. W. Dove. Die Verbreitung der Wärme auf der Oberfläche der Erde, Berlin, 1852; English edition, London, 1853. Die Monats- und Jahres-Isothermen in der Polar-Projection, Berlin, 1864 (for the northern hemisphere).

[10] J. H. Coffin. Winds of the Globe. Smithsonian Institution, Cont. to Knowl., vol. xx, Washington, 1875.

[11] See Edgar W. Woolard. Historical note on charts of the distribution of temperature, pressure, and winds over the surface of the earth, MONTHLY WEATHER REVIEW, 48:408–411, 1920.

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