There was a very noticeable earthquake shock in California on the date of the disturbance at Chequamegon Bay. Whether that fact shall be considered simply as a striking coincidence or whether there was any actual relation between the two phenomena, remains to be determined. We are of the opinion that a tilting of the lake bed by an earthquake shock would have produced a wave of much greater size and geographic extent than was noticed. Forel, in his study of the seiches on Lake Geneva, mentions the fact that while earthquakes frequently produce seiches, there were several sharp shocks that were not followed by seiches.

The theory that it was produced by pressure oscillations seems to be the most satisfactory, if the discrepancy in time could be accounted for. The wave of April 7, 1893, in the lower end of Lake Michigan, was accompanied or preceded by a sharp rise in pressure at several points. The barogram of the Chicago station on that date is shown on the bottom line of Fig. 6. According to Local Forecast Official H. C. Frankenfield the wave occurred between 1:30 and 1:45 a. m., April 7, which corresponds very closely with the time of the marked rise in pressure.

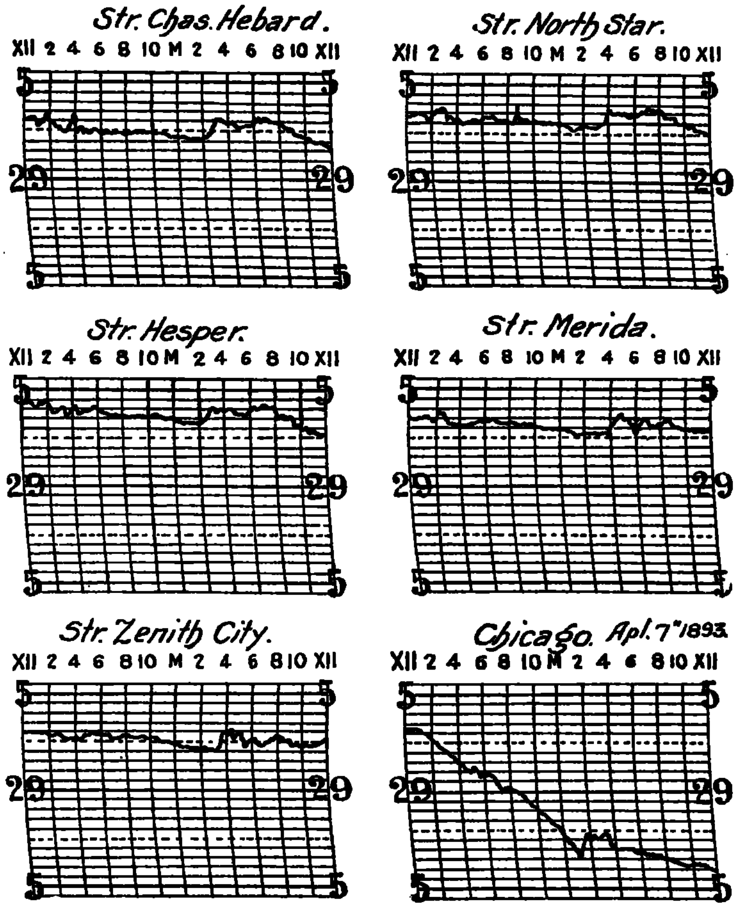

Fig. 6.—Barograms, noon July 21 to noon July 22, 1899.

NOTE.—The barograph clocks at the Weather Bureau stations in Williston and Bismarck, N. Dak., Moorhead and Duluth Minn., run on eastern standard time. Those on the vessels run on central standard time. The steamers *Sacramento*, *Santa Maria*, *Charles Hebard*, and *North Star* were in Duluth Harbor. The *Hesper* was at Superior and the *Merida* and *Zenith City* on the open lake east of the Apostle Islands.

The disturbance in atmospheric pressure on the western end of Lake Superior was local in a relative sense only. It did not extend as far east as Marquette, but, on the other hand, it was felt almost simultaneously from Duluth to the Apostle Islands, and we know not exactly how much farther in an east and west line; neither do we know its extent along a north and south line. It is a fortunate circumstance that pressure oscillations almost invariably extend over very considerable areas and shade off gradually from a maximum at some central point or axis to a minimum several hundred miles distant. There is, therefore, little danger of a large wave being created by such impulses.

It is important to note, in this connection, that the pressure oscillations on land and on vessels lying in the harbors were not so well marked as those on the two vessels in the open lake.

Looking at the results of a sudden increase of pressure from the standpoint of increased weight on the surface of the water, we are not a little surprised at the magnitude of the figures. An inch of mercury is equivalent to about 13.56 inches of water at the temperature of the water on Lake Superior. An increase in the air pressure corresponding to one-tenth of an inch of mercury would, therefore, be equivalent to an increase in the pressure on the lake surface corresponding to the weight of a layer of water 1.356 inches in depth. A cubic inch of water at a temperature of 62° F. and a pressure of 30 inches weighs 252 grains. The increase in weight over a square mile of water surface would therefore be $\frac{5,280 \times 5,280 \times 144 \times 1.356 \times 252}{7,000 \times 2,000}$ = in round numbers a little over 100,000 short tons.

TORNADO, HURRICANE, AND CYCLONE.

By HARVEY M. WATTS, Editor of the Philadelphia Press.

In pursuance of our policy of presenting matters in a popular way that may be useful to teachers in schools, we take pleasure in reprinting the following admirable article by Mr. Watts, who has long been an earnest advocate of honest fair play in the matter of meteorology and weather forecasts.—ED.

Owing to the confusion attendant upon the popular use of the words cyclone, hurricane, and tornado, as if they were interchangeable, it may be well, in these days of tornado and hurricane occurrence, to point out the radical differences between the three great classes of storm phenomena which are known to the United States. To begin with, the tornado is a purely local storm of great intensity and concentrated energy, whose main destructive effects are the result of the almost incredible velocity of its rotary winds that blow spirally into and about its vortex. Though terribly destructive to life and property, it is at the same time the smallest of local weather disturbances, being limited in duration, in the width of its path, and extent of its track. In one case it may last but a few minutes along a track a few hundred feet wide and a mile or so in length; in another it may persist for hours, its path several hundred yards in width and extending from 50 to 100 miles in length. Its forward motion on its track may vary from 15 to 30 to 60 miles an hour, but this speed is insignificant, compared with the velocity of the rotary winds which may have any speed from 100 to 500 miles an hour and over.

The rotary motion of the winds about the central core is the axis of the tornado and is usually made visible by the twisting movement of the funnel-shaped cloud, which is one of the most marked features of the typical tornado, and the actual existence of the rotary winds is made clear by the character of the destruction and the lay of the débris after the tornado has passed by. The tornado is in type nothing more than the familiar dust whirlwind common to city streets on warm or windy days, differing from it only in intensity, not in kind. Though the tornado under given conditions may form in any part of the United States east of the Rocky Mountains, it is of most frequent occurrence in the plains and rolling country of the Mississippi Valley, where topographical as well as meteorological conditions favor the formation and persistence of local whirlwinds of the tornadic type.

Aside from the destructive effects due to the rotary winds, there are in every tornado ascending currents of terrific velocity which rush up the core of the vortex, as a draught of hot air up the center of a tall chimney. As the rotary motion causes a movement of the winds away from the center of the core, the air here is so exhausted that it almost reaches the condition of a vacuum. The result of this is that in addition to the destructive effects of its rotary and ascending currents the tornado causes serious damage by reason of explosive effects, for if the center with its partial vacuum passes over a house in which the air is at ordinary atmospheric pressure, this air blows outward as if gunpowder had exploded within it. In this way some houses are destroyed which escape damage from the whirling winds.

Though not as destructive as the tornado, and hence second to it in importance in this respect in the classification of local storm phenomena, the thunderstorm is a much more extensive weather disturbance. It is not a storm disturbance rotating about a vertical axis, but moves across the country with a comparatively straight front, often many miles in extent, out from under which rushes the wind squall. In depth from front to rear the typical thunderstorm may reach from 5 to 15 miles and more. The destructive effects of a thunderstorm are due to the lightning, hail, the heavy rainfall, which sometimes approaches the character of a so-called cloudburst, and the high winds that make up the familiar outrushing thunder squall, which may occur before or after rain has begun to fall. The squall winds may reach a velocity of 60 miles an hour or so in gusts, and hence may do considerable damage, though the velocity is nothing compared with the rotary velocities of the tornadic winds.

Covering a large area, under favorable conditions, the thunderstorm may endure for hours, and in its track may cover a region from 100 to 250 miles in linear extent. Itself the result of unstable conditions of the atmosphere, it may develop within its sphere of influence secondary disturbances of particularly violent type, and hence it is often the parent of tornadoes, which are small compared with the thunderstorm, while it itself is comparatively limited in comparison with greater weather disturbances that affect the circulation over extensive areas. The thunderstorm is the most extensive of local storms, and between it and the dry squalls of wind, local gusts and tornadoes, there are many variations, none of them, however, being anything but secondary disturbances, whirls and eddies in the general circulation.

The cyclone is differentiated from all local storms, whose operations are confined to a comparatively small region, since it is a weather disturbance, at its smallest, on a large scale, and at times reaches a continental magnitude. The name is of technical not popular origin, and was first used by Piddington, an English meteorologist, to describe the tempests of the Bay of Bengal and other tropical waters. It is a descriptive epithet and refers to the almost circular movement of the winds about a common center, then supposed to be the unvarying characteristic of these great and destructive storms that are called typhoons in the Eastern seas, and hurricanes in the Caribbean and West Indian waters. The word has been generalized in meteorology and is used to denote one of the two types of atmospheric eddies into which the circulation of the air in temperate zones is thrown. These are cyclonic and the anti-cyclonic.

The most destructive of all cyclones, and in fact the most destructive weather outbursts known are the tropical cyclones, the so-called typhoons of the Philippines, China Sea and Japanese waters, the hurricanes of the West Indies, and Atlantic and Gulf coasts of the United States. Though the largest tornado rarely has a diameter of a mile, the smallest of tropical cyclones rarely falls below 100 miles in diameter, and its sphere of destructive influence may range from 100 to 600, even to 1,000 miles. As the hurricane now ravaging the West Indies shows, the tropical cyclone may persist for days, traveling thousands of miles. The point of origin for the tempests that visit our coast is the eastern Atlantic in low latitudes. They cross over to the West Indies, recurve in the Gulf of Mexico, over or east of Florida, and then travel to the northeast, along the coast line of the United States, then out into the Atlantic over Newfoundland, sometimes reaching English waters. By that time they have taken on all the characteristics of a cyclone originating in the temperate zone. The destructive effects of the cyclone are the result of the winds that blow in spirally about its center, which in the front of the cyclone may reach any velocity from 60 to 90 miles an hour. The low pressure of the barometer in the center of the storm and the terrific winds lift up a tremendous sea that raises the tides above the normal, and hence through disastrous floods cause great loss to life and property along the low-lying coasts, as has been the fate of the bayou region of Louisiana and the sea islands of Georgia and South Carolina on numerous occasions. The rainfall is also often excessive and destructive.

Differing from the tropical cyclones merely in degree are the continental cyclones of the temperate zone. These are the largest weather disturbances known, but are not necessarily violent. On the contrary, they often represent a mild, vague, general circulation of the winds about a common center, within which area the rainfall may be light, heavy, nearly continuous, or broken up into separate areas. These cyclones—the real cyclones of the American Continent—may have a diameter of from 500 to 1,500 miles, and even larger, thus covering an area of over 1,000,000 square miles. They persist for weeks, and, traveling from west to east, may go two-thirds of the way around the globe. Save when their vortex is contracted to about the size of that met with in tropical cyclones, 50 to 100 miles or so, the continental cyclones are beneficent rather than destructive factors in the general circulation. When such contraction occurs in the fall, winter, or spring over the region of the Great Lakes, or over the Atlantic, the conditions repeat all the phenomena of a coast hurricane, and may cause loss of life and damage to property by reason of the hurricane velocity of the winds, the excessive rainfall, and the heavy weather on the lakes or at sea. From this it must be clear that the confusion of general cyclonic with local storm or tornado conditions, so common in the West is easily avoidable, as the contrasts are marked and the distinctions based on broad differences. The mere fact that a storm is local, of limited extent, no matter how great its violence, is the first proof that it is not a cyclone, though the tendency in the West and South is to apply the technical term "cyclone" to all violent local outbursts, on the mistaken idea that the word "cyclone" means a tornado and a tornado only. Compared with the tremendous size and appalling character of the Porto Rico hurricane and other tropical cyclones of like destructive effects, such as that of St. Vincent and Barbados last year, the tornado at New Richmond, Wis., was of small account and thunderstorm casualties trivial.

NOTES BY THE EDITOR.

EFFECT OF WIND ON CATCH OF RAINFALL.

From a recent article by Mr. Barwick, published in the Sacramento Record Union, it appears that on the average of many years the rain gages in the city of Sacramento show systematic differences.

The Weather Bureau gage was 57 feet above ground during the first part of the record, but 100 feet above during the latter part. It gives a total annual rainfall of 20.30 inches, on the average for twenty-one years.

The railroad gage at the railroad shops, 56 feet above ground, gave a total annual rainfall of 17.02 inches, on the average for thirty years.

S. H. Gerrish's gage at his residence, near the ground, gives 20.83 inches, on the average for twenty-two years.

The respective months differ among themselves very much in the same proportion in all these records.

The railroad gage is located about a mile north of the Weather Bureau, but Mr. Gerrish's gage is about a mile and a half northeast from the Weather Bureau.

Mr. Barwick says:

There is no doubt in my mind but that the greater part of this difference in the railroad gage is due to the shop buildings, which are all mostly constructed of iron and roofed over with the same material. Then the heat from the many engines in, around, and passing through the railroad grounds causes much greater evaporation than takes place at the point of location of other gages mentioned. Then, again, the readings are taken but once a day, and if the rain ceases for several hours before measurements are made, there must be an appreciable evaporation. The railroad gage being near the south end of the building, the wind on reaching the gage passes over it at a greater velocity than were it located in the center of the roof, and as our storms are with southerly winds, it places the railroad gage to the windward of its position as to the building's location.

C. C. Bonte has suggested placing the gage on a pole in the grass plot near the passenger depot, which would take it from a most undesirable location, and place it in one of the best that could be suggested in that locality, being surrounded by grass all the time, which being irrigated in summer, would reduce the evaporation to a much smaller amount than at its present location. The railroad gage and the Weather Bureau gage being of nearly the same elevation during sixteen years, should not show such a great difference as they do, and the effect of a change in location will be looked for with considerable curiosity by those interested in rainfall records.

As the records by the railroad gage are invariably smaller throughout the year than those of either of the other gages, there is some plausibility in the suggestion by Mr. Barwick that this deficit is due to the evaporation that takes place before the rain is measured. This evaporation can be greatly diminished by a better construction of the gage, but at best, is liable to be appreciable in a very dry atmosphere. If the gage at the railroad shops were so located as to be in the lee of a tall building it would catch less by reason of the interference of the building; but this does not seem to be the case. On the contrary, the railroad gage is so placed on the roof near the south end of the building that the wind strikes it with greater velocity than at almost any other location that could have been chosen; therefore, it can not be said that the gage gives a deficit because it is sheltered by a building. The great velocity of the wind at the gage seems to have suggested to Mr. Barwick the idea that there would be also a corresponding amount of evaporation. This is a true cause for a deficit, but it is hardly sufficient to explain the total annual deficit of 3.5 inches, or 15 per cent of the 20.5 inches that ought to have been recorded annually. It would be very easy for the local observer to pour a given quantity of rain water into a gage in this locality and determine, by measurement, how much evaporates every day, and calculate what would be the average amount of evaporation between the close of any rain and the time when the daily measure-