which was the horse, was taken out with only slight injuries; the horse was badly injured.

The eight-room cottage that we occupied before the storm (indicated on map at *a*) was partially wrecked and the roof was taken off. At *c* a one-story barn was blown away. At *d* another one-story barn was destroyed. At *e* a heavy log corncrib was blown down. At *f*, about one mile to the westward, a box car, remodeled to live in, was torn to pieces; Mr. Lambert and family left the car just before the storm struck. About three miles southwest of my place a four-room cottage occupied by Mr. George Locke (indicated on map at *g*) was partially destroyed; the family of seven left the house for the open at the beginning of the storm; one of the children was blown away from the party against a fence and severely injured. Fortunately my family were away. The average width of this storm's track was about 200 yards, being about one-third of a mile wide at point of greatest destruction. For half a mile to the east of my cottage and the same distance west, even the earth was torn up along a path averaging 30 feet in width; chunks of grass were wedged between the wreckage, and the path resembled the effects one would naturally expect from a huge stream of water more than 25 feet in diameter directed along the ground with great force, instead of from wind. The rainfall attending the storm was only moderate, starting with large scattered drops just before the storm struck. One mile or so to the northward there was some hail and roads were washt by excessive rains. The course of the storm was west-southwest to east-northeast; I traced it to the eastward and find that it past about one mile south of Bluff Springs. There was very little lightning and only moderate thunder.

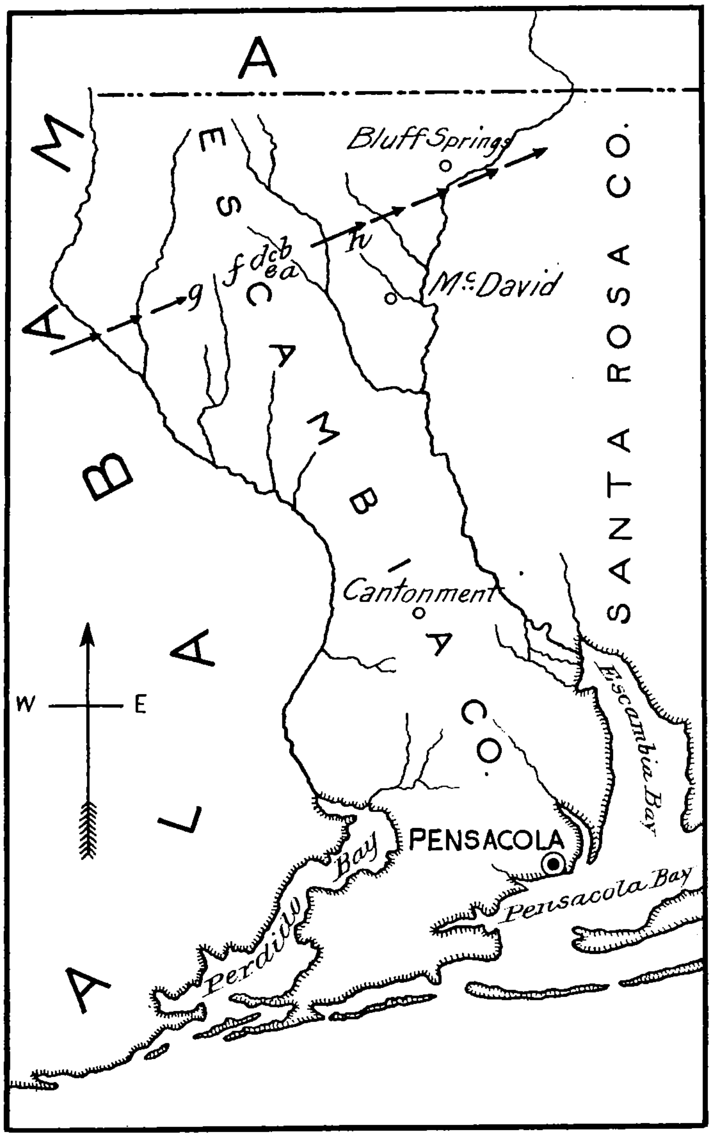

FIG. 1.—Map of Escambia County, in western Florida, showing track of tornado of April 5, 1907.

A report from Mr. J. P. Harrison, McDavid, Fla., states that the tornado late in the afternoon of the 5th past mostly thru the timber region northwest of McDavid, destroying a house belonging to Mrs. Mollie Evans and Mrs. Margarette Williams (indicated on map at *h*).

Cloud very bright, followed by heavy black cloud resembling heavy black smoke, continually mixing and rolling together. Very little lightning. Heavy rain. No hail. Previous to the storm there was a roaring, deadening sound.

Escambia County, Fla., has been visited by three tornadoes since March 1, 1905, not to mention the hurricane of September 26–27, 1906. A tornado occurred March 20, 1905, near Bluff Springs; a smaller one near Cantonment April 14, 1905, and the one of this April (1907) also past near Bluff Springs.

A PROPOSED NEW METHOD OF WEATHER FORECASTING BY ANALYSIS OF ATMOSPHERIC CONDITIONS INTO WAVES OF DIFFERENT LENGTHS.

By HENRY HELM CLAYTON. Dated Hyde Park, Mass., May 4, 1907.

It has been known for a long time that when an average of the temperature, pressure, or any weather condition is obtained for a week, month, or other period, the resulting mean will differ for successive intervals, even after allowance has been made for the known annual and diurnal variations. By many meteorologists it is still considered debatable whether these variations are merely unbalanced, accidental variations, subject to no law, or whether they represent variations under the rule of forces which may be ascertained, and predictions of the variations may be made. I believe that such laws can be found, and I have spent many years in a laborious search for them.

In the American Meteorological Journal of July, 1885, and again in the same journal of June, 1891, I quoted data which seem to me to show clearly that, in the oscillations of pressure and temperature in the United States, there may be detected at least two sets of waves, one of which travels rapidly from west to east and the other much more slowly. Chambers and Sherman had also pointed to evidence of a similar nature.[1] But, so far as known, the drift of atmospheric conditions, other than that apparent on the ordinary weather map, was sporadic and irregular, sometimes being relatively rapid and at other times very slow, and therefore furnished no basis for accurate forecasting. Moreover, such movements are so disguised that they are not readily recognized, and have received but little attention.

Meteorologists have turned their attention to other aspects of the subject, such as (1) periodic changes; (2) the shifting of the centers of action of the atmosphere, as, for example, the shifting of the center of high pressure near the Azores, or the shifting of the center of low pressure near Iceland; (3) seesaw oscillations of pressure and other weather conditions between widely separated areas, as between India and Russia, or India and South America, or between Iceland and the Azores.

After considerable research along these lines,[2] I have arrived at the conclusion that, for purposes of forecasting, the study of the laws underlying the drift of weather conditions is the most promising line of research, and that the conditions of high and low pressure, temperature departures, etc., shown on the weather map, should not be regarded as individual units, each having a drift of its own, but rather as a complex, kaleidoscopic effect, produced by atmospheric conditions progressing from place to place at different speeds and, perhaps, from different directions. When one turns a kaleidoscope, the bits of glass, moving different distances, fall into a new arrangement; so, in the course of a day, the different atmospheric conditions, changing or moving with different speeds, assume the momentary relations which are shown by successive daily weather maps. Figs. 1, 2, 3, and 4 are given here

[1] Nature, vol. 23, Nos. 4 and 5, and Amer. Meteor. Journal, vol. 1, No. 7.

[2] See paper showing oscillation about certain centers in Amer. Meteor. Journal, Jan., 1884, and April, 1885, and also various papers on periodic changes in same journal.

to show that the ordinary changes in temperature and pressure may be analyzed into different classes, distinguished by different rates of change, and that each class is dependent on some atmospheric condition moving from place to place with a velocity peculiar to that particular class and different from that of every other class. These examples were selected at random. Fig. 1 is reproduced from an earlier paper in the American Meteorological Journal, vol. 8, p. 65, June, 1891. In this figure the vertical lines represent differences in time of five days, between January 1 and February 9, 1888, and the horizontal lines show differences in temperature of 10° F. The unbroken curves show the normal temperature at four stations in the United States, namely: Fort Assinniboine, Mont., latitude 48° 32′ N., longitude 109° 42′ W.; Yankton, S. Dak., latitude 42° 54′ N., longitude 97° 28 W.; Marquette, Mich., latitude 46° 39′ N., longitude 87° 24′ W., and Eastport, Maine, latitude 44° 54′ F., longitude 66° 59′ W. The dotted curves show plots of the current temperatures observed at these same stations between January 1 and February 9, 1888.

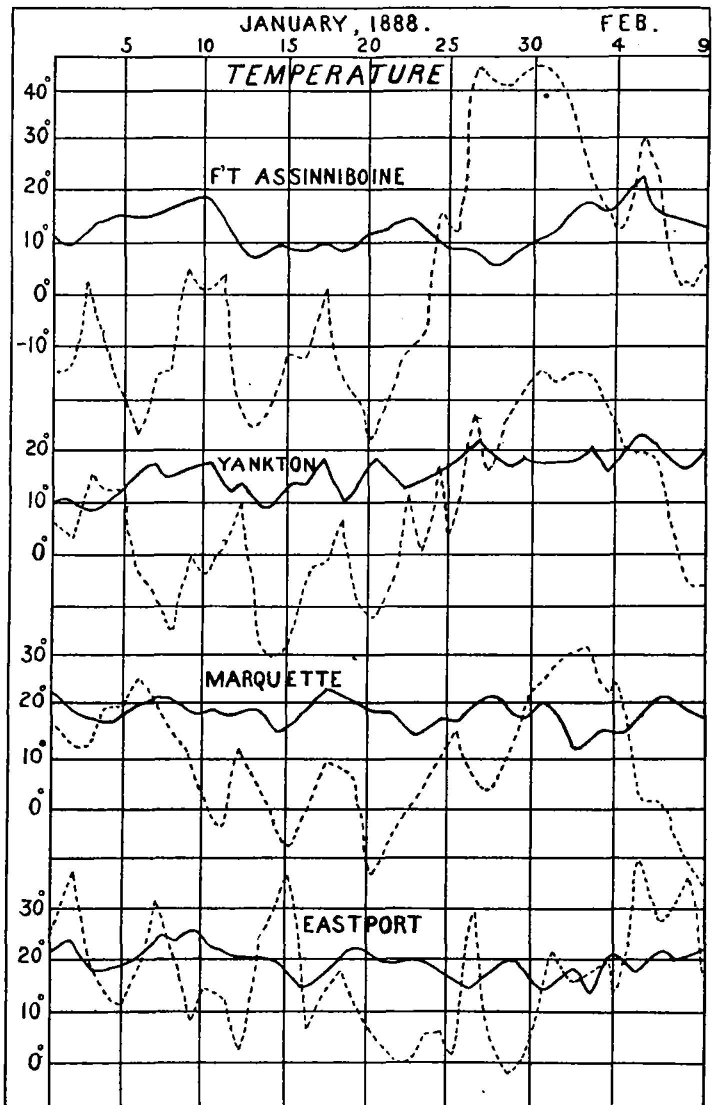

Fig. 1.—Normal and observed temperatures at four stations, January 1 to February 9, 1888.

At each of these stations, the curves show that, besides the minor fluctuations from day to day, there was a prolonged period when the temperature was below the normal, followed by a period when the temperature was above the normal. The prolonged period of abnormal cold began at Fort Assinniboine on December 25, and the greatest departure below the normal occurred on January 6. It began at Yankton on January 5, and the greatest departure from the normal occurred on January 14. It began at Marquette on January 7, and the greatest departure occurred on January 20. It began at Eastport on January 16, and the greatest departure occurred on January 29. This period of cold was followed by a shorter period of abnormal warmth which occurred about ten days later at Eastport than at Assinniboine, indicating a velocity somewhat over one thousand miles a week. This is more rapid than the movement of the preceding area of cold, but still much slower than the warm waves accompanying our usual winter storms, which move nearly one thousand miles a day. These storm waves are shown by the more rapid fluctuations in the dotted curve of fig. 1, which are found at Eastport only three to four days later than at Fort Assinniboine.

Fig. 2 is plotted from observations of pressure, from January 1 to February 9, 1901, at Williston, N. Dak. (latitude 48° 9′ N., longitude 103° 35′ W.), Duluth, Minn. (latitude 46° 47′ N., longitude 92° 6′ W.), Chicago, Ill. (latitude 41° 33′ N., longitude 87° 37′ W.), and Boston, Mass. (latitude 42° 21′ N., longitude 71° 4′ W.). In this plot, vertical lines represent differences of one day, and horizontal lines, differences of one-tenth of an inch of pressure. The continuous curves show the observed fluctuation of pressure at the various stations from January 1 to February 9, 1901.

The curves show that the maxima and minima of pressure indicated by the numerals 1, 2, 3, etc., moved very rapidly from west to east, taking about three days to move from Williston to Boston. If, however, smooth curves, like those shown by the broken lines, be drawn thru these rapid fluctuations and the maxima and minima are marked *A*, *B*, *C*, etc., there is evidence that, underlying these rapid fluctuations of pressure, there are slower oscillations or waves, which move more slowly than the ones marked with the numerals. For example, the time taken for the maxima and minima marked *A*, *B*, *C*, etc., to move from Williston to Boston is about five days. This time is nearly twice as great as that required for the more rapid fluctuations marked 1, 2, 3, etc., to traverse the same distance. Again, by drawing a dotted curve thru the mean points between the maxima and minima, *A*, *B*, *C*, etc., there are shown still longer oscillations of pressure which travel much more slowly than either of the sets of fluctuations marked 1, 2, 3, or *A*, *B*, *C*, etc.

By reading the values of the curve *A*, *B*, *C*, etc., from the plot for each twelve hours and subtracting them from the observed values, the shorter fluctuations are separated from the longer and may be plotted separately, as in fig. 3. Then by plotting the readings of the curve *A*, *B*, *C*, etc., fig. 4 is obtained. Thru the maxima and minima of this curve is drawn a broken curve which shows the longer, slow-moving oscillation or wave, the minimum of which occurs about ten days later at Boston than at Williston.

To analyze such curves graphically is, however, more or less arbitrary, and different sets of curves would be drawn by different persons from the same data. Another method of analysis is by means of numerical averages. If, as in the present series of curves, the interval between the maxima and the minima of the more rapid fluctuations is two to three days, these may be smoothed out by taking the numerical mean of all the observations of three days and doing this successively, beginning at each observation for a new mean. The resulting means, when plotted, give curves like those marked *A*, *B*, *C*, etc., in figs. 2 and 4. The maxima in these curves are separated by intervals of from five to seven days. Using the values from which the curves *A*, *B*, *C*, etc., are plotted and taking means for successive intervals of six days the oscillations *A*, *B*, *C*, etc., are smoothed out, and there result numbers from which a plot like that shown on the broken curve in fig. 4 is derived. By subtracting the smoothed values for three days

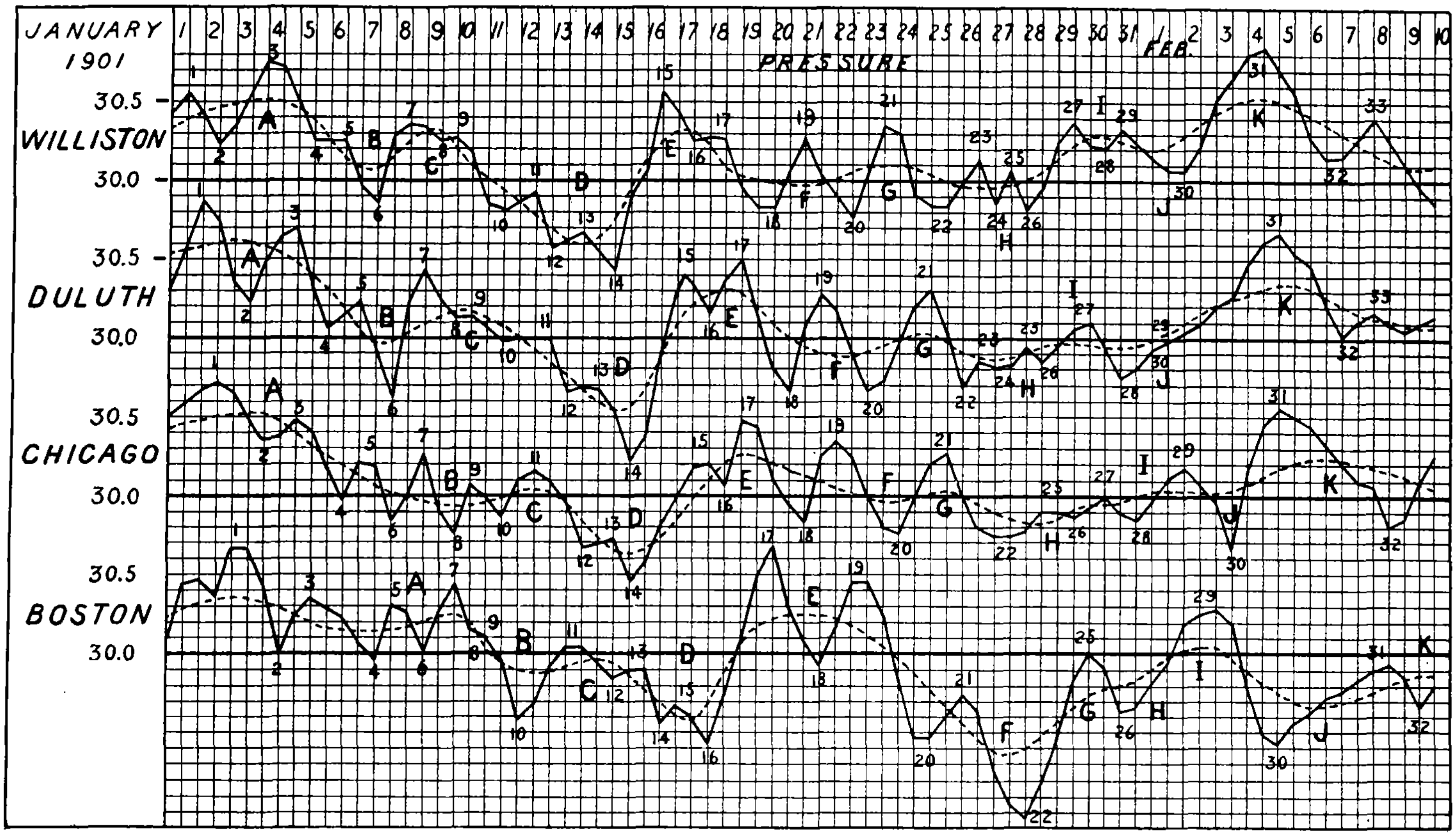

FIG. 2.—Pressure at four stations, showing observed pressure and a smooth curve, January 1 to February 9, 1901.

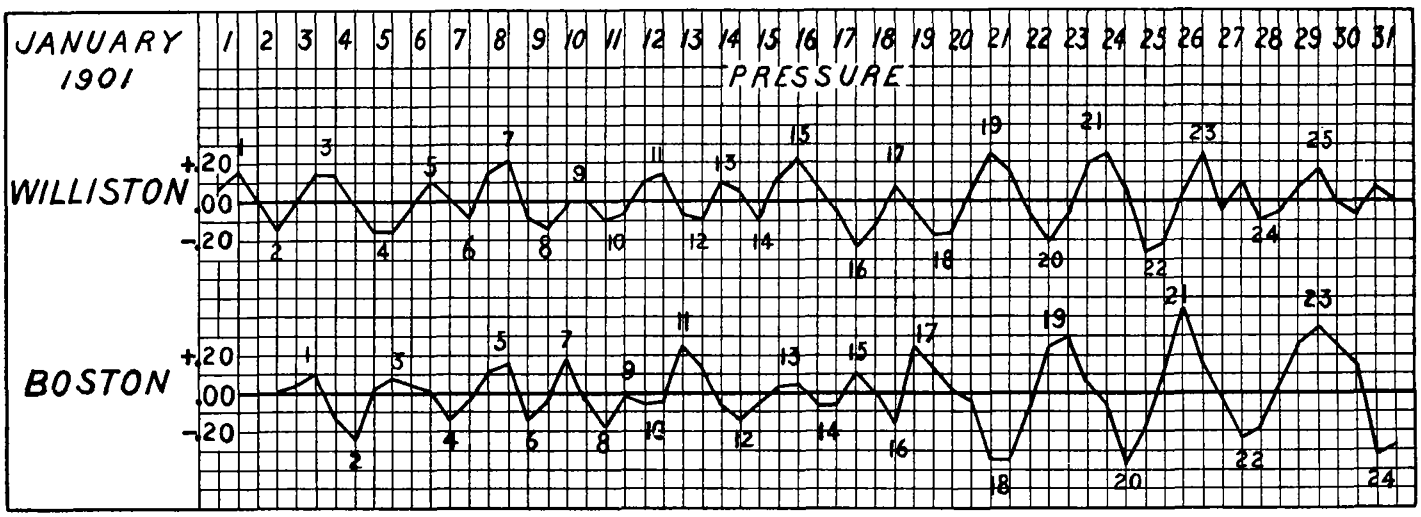

FIG. 3.—Departures of observed pressure at two stations from smooth curve values, showing shorter fluctuations, January, 1901.

from the observed values, the oscillations marked 1, 2, 3, etc., may be separated from longer oscillations; then, by subtracting the means of six days from the means of three days, these oscillations may be separated from those of longer periods, and so on successively.

Analyses of the observed values of temperature at 13 widely separated stations in the United States were carried out consecutively for the three years 1897, 1898, and 1899. The selected stations were Boston, Mass., Hatteras, N. C., Key West, Fla., Buffalo, N. Y., Chicago, Ill., Little Rock, Ark., Galveston, Texas, Williston, N. Dak., Denver, Colo., El Paso, Texas, Salt Lake City, Utah, Seattle, Wash., Los Angeles, Cal.

23——2

This work, finished as long ago as 1901, disclosed the fact that this complex set of waves occurs continuously and travels across the United States in a general west to east direction, each wave moving with a velocity and direction of its own, the velocity being in general inversely as the wave-length measured in time—that is, short waves move rapidly and longer waves more and more slowly, in proportion to their length. The diagrams, figs. 5 to 28, Plates I, II, and III, are given to illustrate the progressive motion of the three classes of waves shown in figs. 3 and 4. In preparing these charts the observed temperature data were separated into different classes of waves in the manner described above, and for the 13 stations named. The rapid fluctuations, such as those marked 1, 2, 3, etc., in

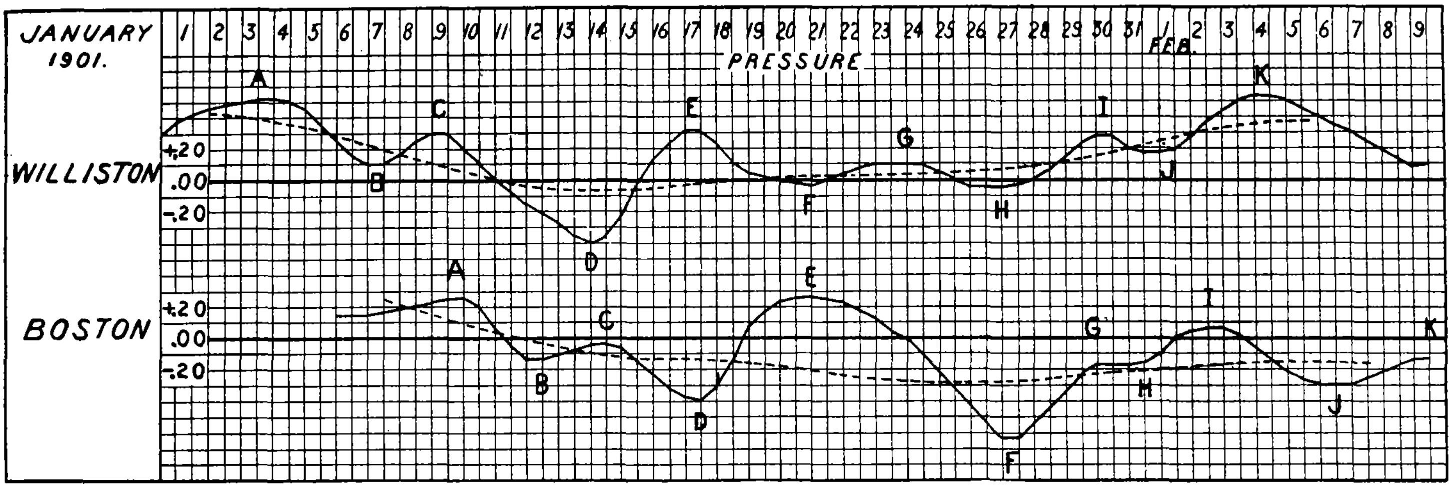

Fig. 4.—Smooth curve values of pressure at two stations, showing longer fluctuations, January 1 to February 9, 1901.

figs. 2 and 3, where the crests of successive waves are only two or three days apart, were charted for successive days in figs. 5 to 12, Plate I. The residuals obtained after eliminating the other classes of waves were used for this purpose and lines of equal values were drawn. In this and the succeeding charts, the mean values and equal values above the mean are connected by continuous lines, while equal values below the mean are connected by broken lines. The charts for successive days show that waves of this class move from west to east very rapidly and cross the United States in about three days. The diagrams, figs. 13 to 20, Plate II, show the progressive movement of a class of waves like those marked *A*, *B*, *C*, etc., in figs. 2 and 4. The crests of these waves are five to nine days apart, and the progressive movement is so much slower than the movement of the waves of Class I that about six days are occupied in crossing the United States. The diagrams, figs. 21 to 28, Plate III, show the progressive movement of waves of a class indicated by the broken curve in fig. 4, in which the crests of the wave are about a month apart. Waves of this class move so much more slowly than the preceding waves that the diagrams are given for successive intervals separated by four days instead of one day.

Meteorological waves of this class take from nine to sixteen days in crossing the United States, and their arrival on the eastern coast may be predicted for more than a week in advance.

There are longer waves which travel even more slowly than do waves of Class III, but the progressive movement of the longest waves is more or less complicated by oscillations about centers and can not be followed so easily as the shorter waves.

The waves of different classes not only move from place to place with a velocity different for each class, but occasionally move from directions at right angles to one another. That is, a wave of one class moving from the southwest may exist simultaneously with waves of another class moving from the northwest, and the condition may last for several weeks.

It seems to me that these facts prove the separate, physical existence of such waves.

When lengths of oscillation, or the times from crest to crest of successive waves are taken as ordinates, and rates of travel from place to place are taken as abscissas, a plot of the observed data shows a flat curve of the nature of a parabola.

The results of this investigation have led me to the following important conclusions:

(1) That every meteorological element at any given place may be analyzed into a definite number of oscillations or waves differing in length, each of which appears to have a physical existence distinct from that of the others.

(2) When analyzed in the same way, for any given time, the data at widely separated stations near the same latitude show analogous waves, except that the maxima and minima differ somewhat in the time of occurrence at the different stations.

(3) The waves, at least in temperate latitudes, drift generally from west to east—that is, the maxima and minima occur at eastern stations later than at western stations.

(4) The velocity of drift is inversely proportional to the wave length. Fluctuations, or oscillations, completed in a short period of time drift rapidly, while longer fluctuations drift more and more slowly in proportion as the time of oscillation is longer.

(5) The speed of travel appears to be fairly constant from year to year for waves of the same length of oscillation measured in time.

The discovery of these facts not merely opens the way to a great improvement in the forecasting of weather from day to day, but also, I believe, furnishes a scientific basis for long-range forecasting. The application of this knowledge to practical work is, however, not easy because of the difficulty of analyzing and separating the different classes of waves. As a result of working at the matter for a number of years and carefully developing and testing methods of analysis and charting, I believe it is possible to improve the present forecasts and to make forecasts longer in advance, which would be of enormous advantage to agriculture and commerce.

I have employed at different times to assist me in this work Mr. John P. Fox and Miss M. L. Davenport. Their patient industry and various suggestions have enabled me to accomplish the large amount of work necessary to develop and test the conclusions presented here. I am indebted to Prof. H. S. Mackintosh for a revision of the manuscript.

Plate I. Progressive Movement of Temperature Waves of Class I, February 23 to March 2, 1899.

Fig. 5. February 23, 1899.

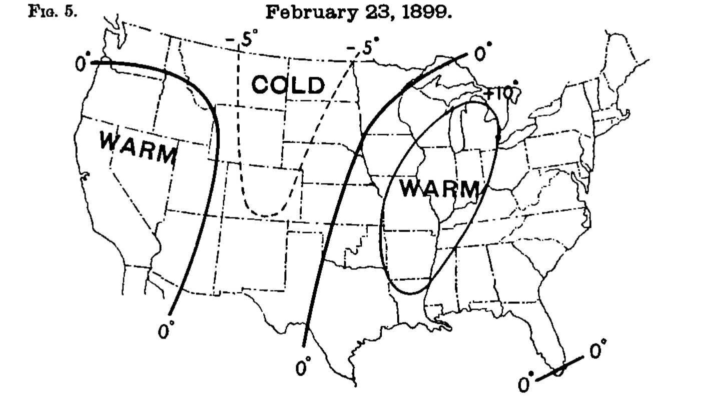

Fig. 6. February 24, 1899.

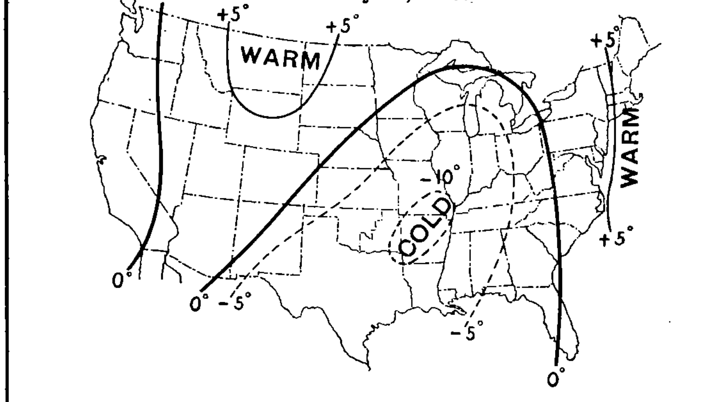

Fig. 7. February 25, 1899.

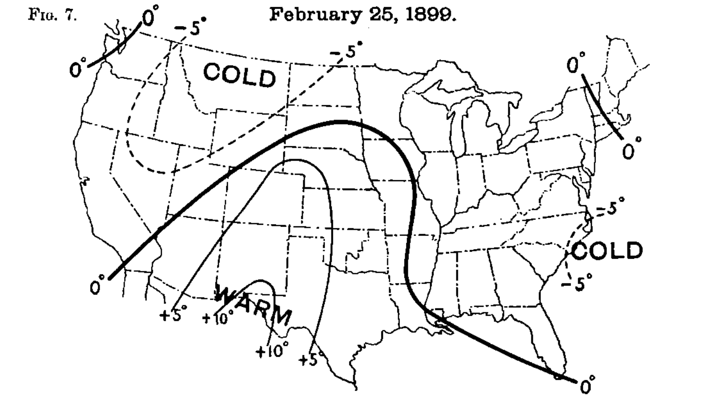

Fig. 8. February 26, 1899.

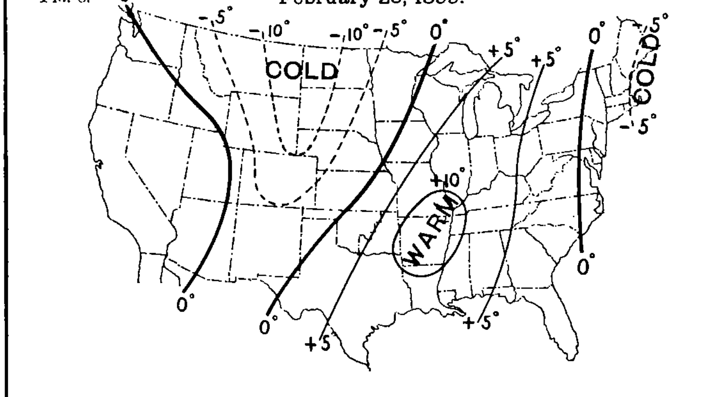

Fig. 9. February 27, 1899.

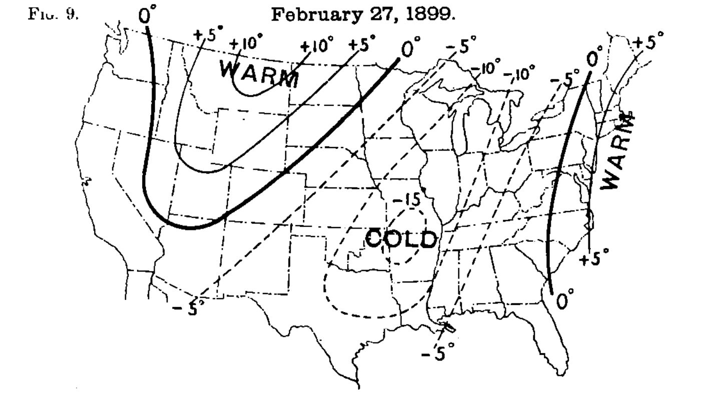

Fig. 10. February 28, 1899.

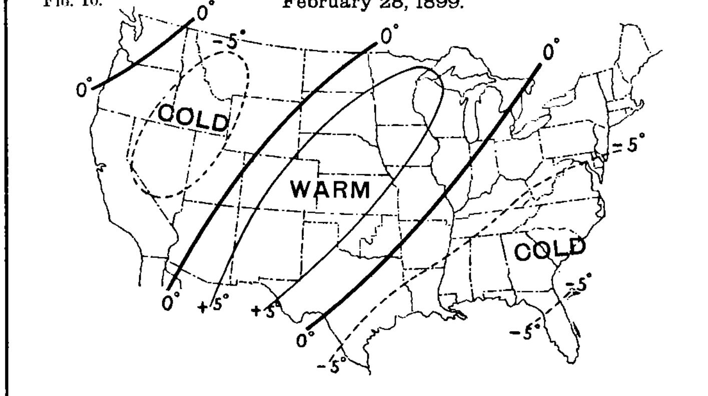

Fig. 11. March 1. 1899.

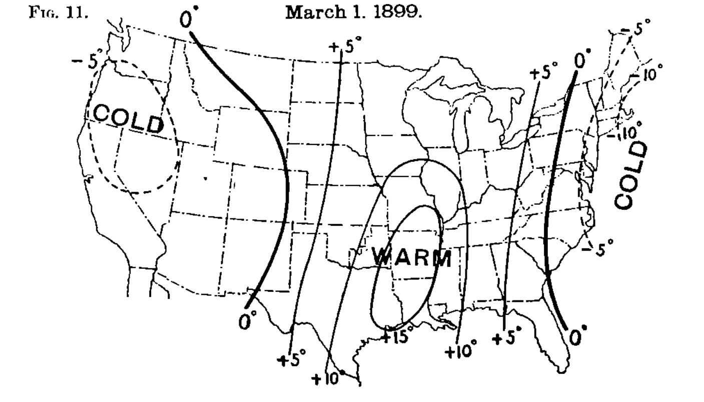

Fig. 12. March 2, 1899.

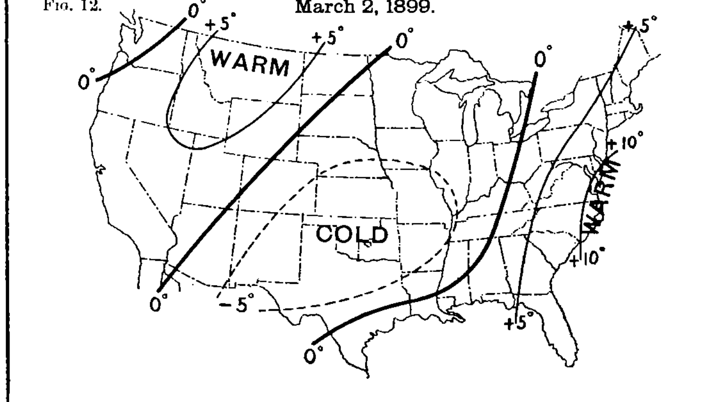

Plate II. Progressive Movement of Temperature Waves of Class II, February 25 to March 4, 1899.

Fig. 13. February 25, 1899.

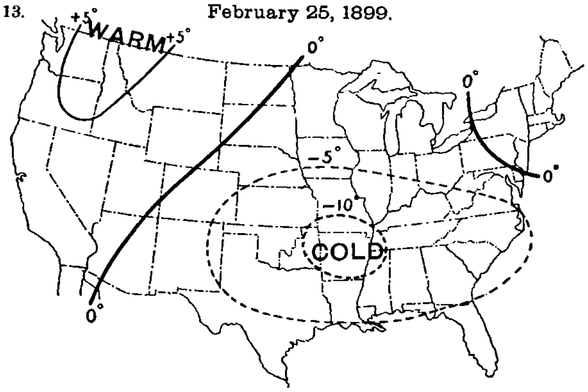

Fig. 14. February 26, 1899.

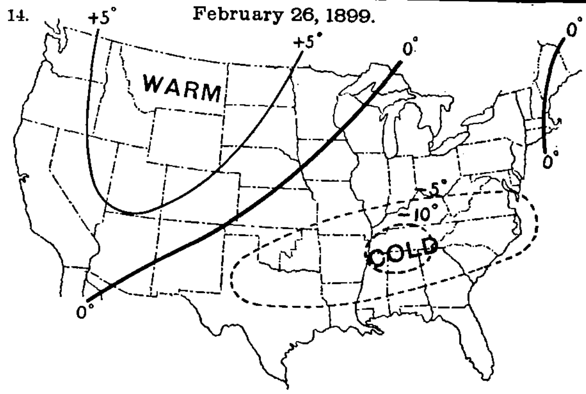

Fig. 15. February 27, 1899.

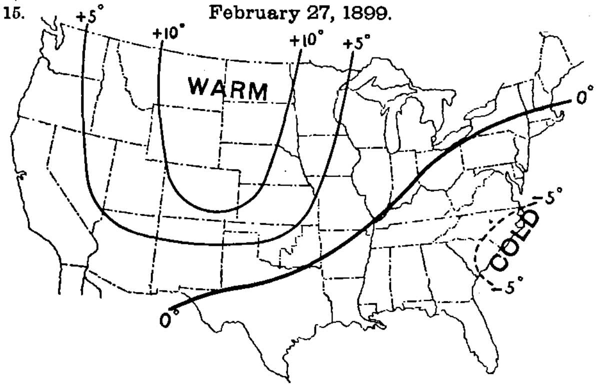

Fig. 16. February 28, 1899.

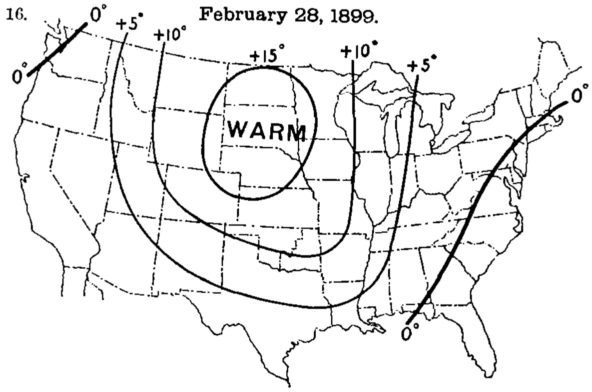

Fig. 17. March 1, 1899.

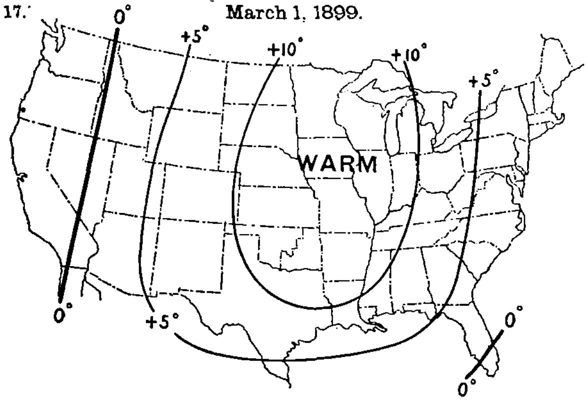

Fig. 18. March 2, 1899.

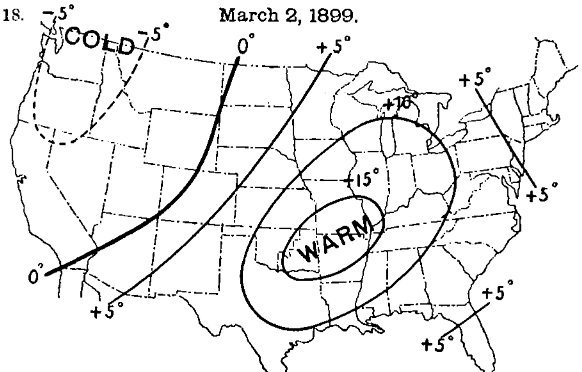

Fig. 19. March 3, 1899.

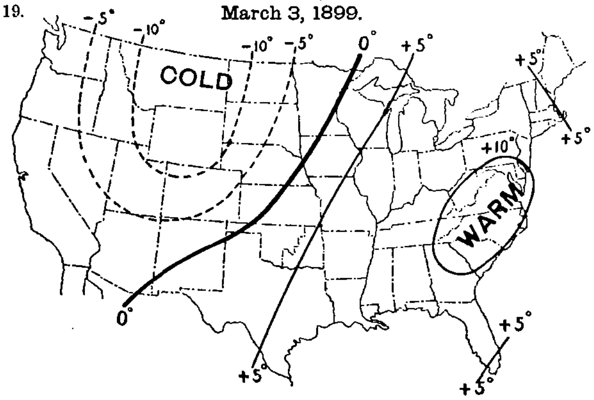

Fig. 20. March 4, 1899.

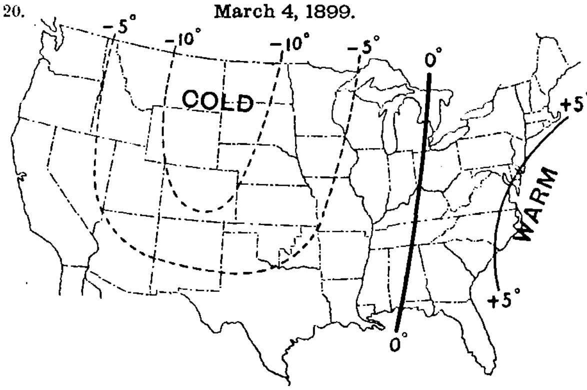

Plate III. Progressive Movement of Temperature Waves of Class III, February 2 to March 2, 1899 (4-day intervals).

FIG. 21. February 2, 1899.

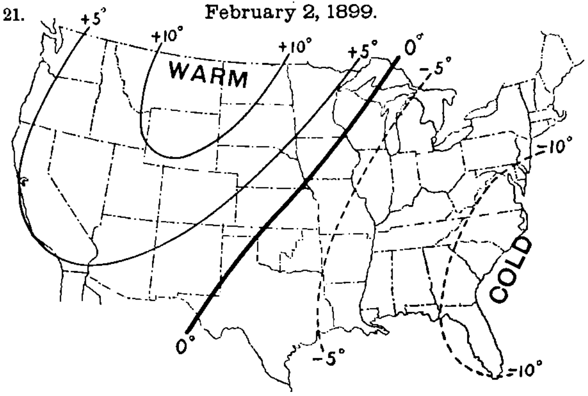

FIG. 22. February 6, 1899.

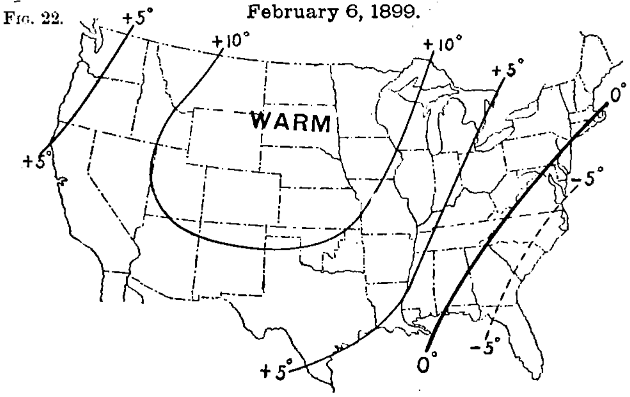

FIG. 23. February 10, 1899.

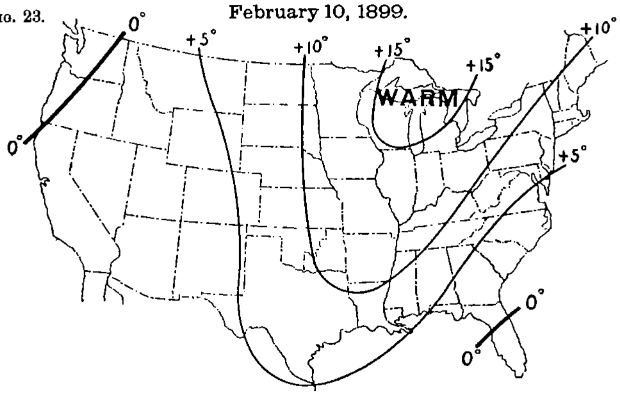

FIG. 24. February 14, 1899.

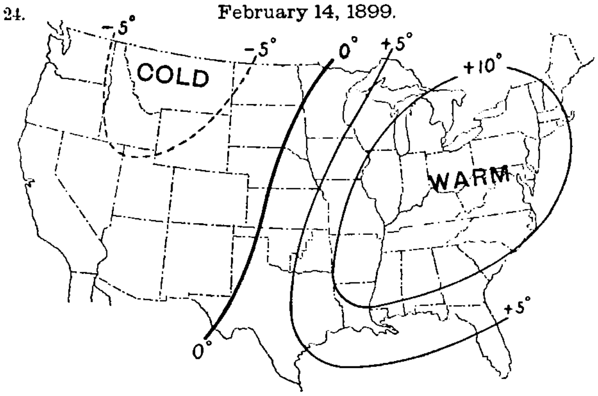

FIG. 25. February 18, 1899.

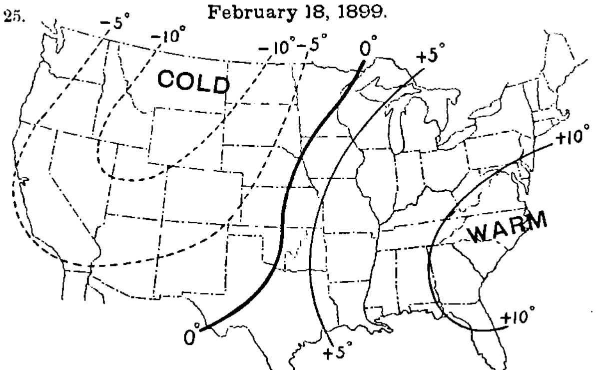

FIG. 26. February 22, 1899.

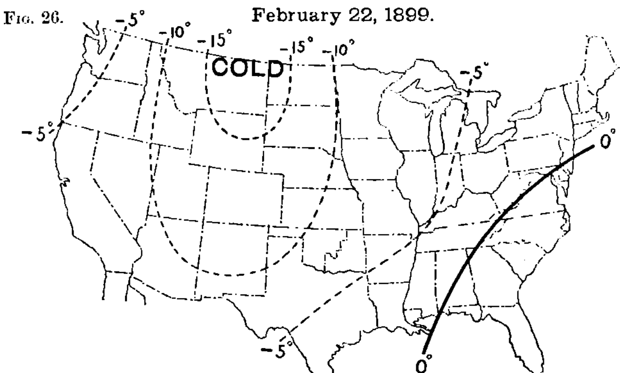

FIG. 27. February 26, 1899.

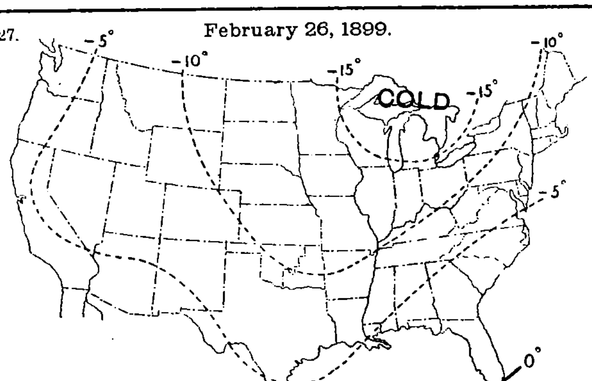

FIG. 28. March 2, 1899.