possible to get up with the kites, it is found that the wind is strong and from the west less than a thousand feet above the ground. There is always a big inversion of temperature often amounting to about 30° F. about 500 feet up. This warm air floating above the cold, almost calm surface air causes the inverted image to appear above objects near the horizon. This effect is related to the chinook from the Rockies. The high temperature aloft may come down, but more often there is a big temperature inversion for a few days and then the warm stratum of air disappears.

Sometimes during such pressure distribution, i. e., a HIGH near Utah and a LOW north of Montana or the Dakotas, the effect of the chinook is felt near the ground. The wind is from the southwest to northwest on the surface and aloft it is directly west. Instead of being strong on the surface and light aloft, as in the blizzard, it is light on the surface and very strong aloft. The temperature at this time is much higher above the ground than at the surface and continues so during the entire period of the warm wave, as shown by kite flights in series of November 17 and December 3–4, 1919. The surface wind increases in strength and warmth during the day, but the wind is not so dry and warm as when it crosses the regions nearer the mountain slope, because it has been absorbing moisture and losing heat for a great distance. Nevertheless it is still very warm and dry and fairly eats the snow.

WEATHER FORECASTING.

By H. H. CLAYTON, Chief Forecaster.

[Argentine Meteorological Office, Buenos Aires, Argentina, Feb. 3, 1920.]

The very interesting discussion of weather forecasting by Prof. V. Bjerknes in the MONTHLY WEATHER REVIEW of February, 1919, leads me to recount how a somewhat crude conception of his methods arose in the United States Weather Service, and to suggest how certain relations of the wind to the gradient may be utilized.

In 1892, when acting as local forecaster of the Boston section, I was called into Washington with other local forecasters for the study of the methods in use in the Central Office. There I encountered Mr. Bassler, of Cincinnati, and Mr. Wappenhans, of Indianapolis. In the course of our various discussions Mr. Wappenhans pointed out his use of a line drawn through a low area separating the winds having a northerly component from those having a southerly component of motion. He said it was useful in predicting rain, changes of temperature, and changes of wind. I began drawing these lines and soon convinced myself of their usefulness in predicting weather changes a short time in advance and hence especially useful to a local forecaster. Mr. Wappenhans offered no reason for the observed relations, but I concluded that the rains observed along the line indicated were due to the underrunning of the warm southerly by the cold northerly winds, whereby the southerly winds were chilled by expansion and their moisture condensed. If this was so, I reasoned that besides the line running nearly north and south, which Mr. Wappenhans drew, there might be another nearly east and west separating the cold winds on the northeast side of the cyclone from those on the southeast side. These two lines run nearly at right angles to each other, as is illustrated by the dotted lines in figure 1. In making local forecasts at Boston I frequently drew these lines, either actually or mentally, and I soon found that they were both lines of converging winds. I came to consider the convergence of the winds as the main factor to be considered as the cause of rain and associated fair weather with diverging or parallel winds. It seemed to me that this view was confirmed by tropical cyclones around which there were no great difference in temperature, yet the converging winds produced ample rainfall.

Later, as meteorologist of the Blue Hill Observatory, I became associated with Mr. John P. Fox, who volunteered to assist in certain lines of research. Among those we took up the question of converging winds. The evidence showed clearly that rainfall was intimately associated with converging winds, and Mr. Fox discovered that the quantity of rainfall was related to the steepness of the gradient. In other words, the more rapid the converging winds the greater the rainfall. It was evident also that humidity was a factor, because with equal convergence the rainfall was greater near the coast than over the interior. This work was done between the years 1898 and 1903, but never published, because it was considered incomplete and was laid aside owing to the pressure of other work with the intention of taking it up and completing it later. In 1912 the idea was presented to the officials of the Weather Bureau at Boston and at Washington with examples taken from current weather maps. In 1916, with slight modifications, the essay thus prepared was offered for publication in the WEATHER REVIEW and appeared in the MONTHLY WEATHER REVIEW of February, 1916.

At that time I had not seen the masterly studies of Prof. Bjerknes and Mr. Sandström, who deserve all the credit of originating the theory and putting it on a sound scientific basis; also for first publication. That the facts underlying the theory had been partly outlined by others is a testimony to the truth.

I have not yet seen all of the published results of these able workers, but their researches printed in the MONTHLY WEATHER REVIEW contain no mention of certain phases of the question which I believe can be used by forecasters in anticipation of the numerous observations and the drawing of stream lines as advocated by Prof. Bjerknes. Owing to the great irregularities of local winds it is difficult to draw correct stream lines from a scattered network of stations, but it is possible to draw fairly correct barometric lines, hence I am accustomed to draw stream lines from the observed gradients, using observed winds simply as guides to the inclination of stream lines to the gradients. In the average for land stations in temperate latitudes the wind has an inclination of about 45°. Drawing winds at this angle to the isobars, but making the inclination somewhat less where the isobars are crowded, we get a system of stream lines like that developed in figure 1. The drawing of the stream lines as applied to an actual case in the Northern Hemisphere is shown in figure 2. (See dotted lines.)

Where there are no well-developed HIGHS and LOWS, but the isobars have a wavy form, as illustrated in figure 3, the relations may be embodied in the general statement that isobars concave to the gradient induce converging winds resulting in ascending currents, cloudiness, and rain, while convex isobars induce divergent currents with descent of air and fine weather.

In figure 3, L indicates the direction in which the pressure is low and H the direction of high. L' shows the

V-shaped depression described by Abercrombie in which the convergence is large and the opposing winds give rise to active condensation. Drift is also a factor tending

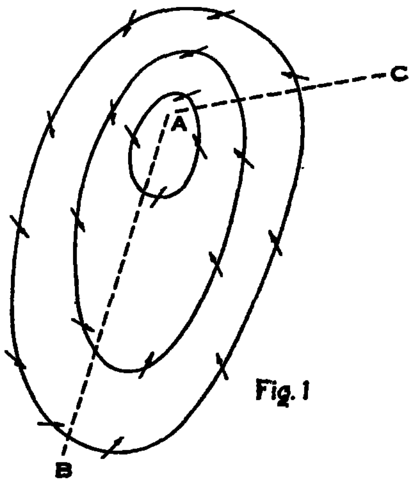

Fig. 1

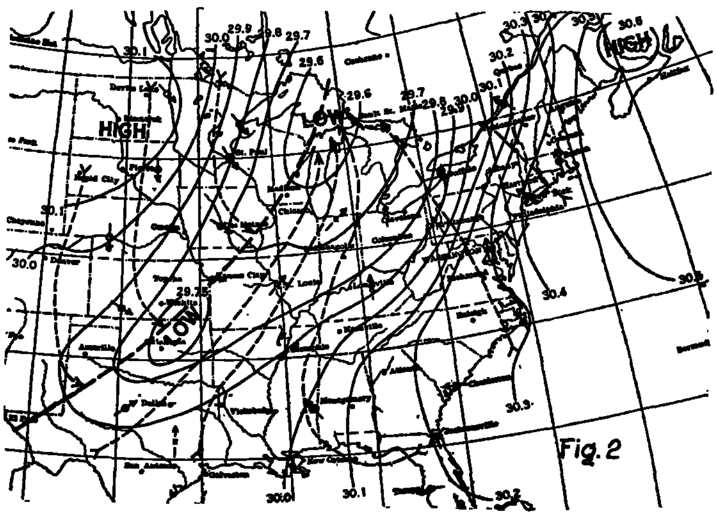

Fig. 2

NOTE.—Figure 2 is from weather map of Jan. 23, 1913. (Broken line shows division between northerly and southerly winds, dotted lines out the directions of flow.)

to modify the component of ascent, increasing it on the side toward which the LOW is drifting and diminishing on the opposite side. Differences in density also play a part, all of which will no doubt be computed and allowed for in the completed scheme of Prof. Bjerknes.

My method of applying these principles to forecasting is as follows: By means of the pressure changes for 12 and 24 hours and their direction of drift I anticipate the changes to be expected during the next 12 or 24 hours. These predicted changes are then added to the pressure distribution of to-day in order to anticipate the pressure distribution of to-morrow.

On the map showing this pressure distribution a system of stream lines is projected in the manner described above.

Another phase of this question of rain areas is one of great interest and possible practical application for precise forecasts made for short intervals in advance. In our investigations Mr. Fox and I found that the rain areas usually could be followed from place to place as easily as areas of low pressure or other meteorological phenomena.

By means of the reports of the volunteer observers of New England we traced the progress of rainfall areas

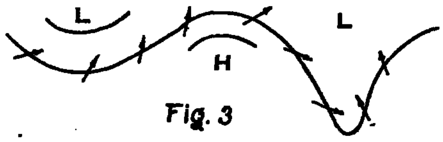

Fig. 3

across New England for several years and reached the conclusion that, if telephonic reports of the beginning of rain could be obtained from western and southern New England, it would be possible to predict approximately the hour of the beginning of rain in Boston. Prof. F. E. Nipher had already suggested the possibility of this in the case of thundershowers, but we found it possible to follow and to predict the progress of rain at all times of the year.

The manager of the Bell Telephone Co. of Boston was approached on the subject of making a trial of a scheme of forecasting rain in this way.

A submanager who was authorized to consider the project reported favorably on the plan, but no action was authorized by the directors.

Later Mr. Fox interviewed the Telephone Co. of New York on the same project without success.

I still consider the plan a feasible one, however, and it only wants energetic action by a sufficiently powerful organization to insure its success.