each side of the low center, and tangent to the outer closed isobar.

Assuming that there be moving eastward at a uniform rate of progression on a given map, in the same latitude, a symmetrical low preceded by a symmetrical high; suppose these to be in tandem formation, of equal area and uniform pressure gradients, and that neither undergoes any change in configuration of isobars, in pressure level, nor in the linear distance from the center to center in a given interval of time. Then at the end of the given time interval, the region of maximum pressure fall will be along a straight line extending from the position of the center of the low at the end of the assumed interval to the position of the center of the preceding high at the beginning of the assumed interval. This is shown by the red lines on the chart figure 5, which represents an ideal weather map on which only one low and one high appear. On this chart (XLIV–38) A is the position of the center of the low at the beginning and A_1 the position of the center of the low at the end of the assumed interval; similarly B is the position of the center of the high at the beginning and B_1 the position of the high at the end of the assumed interval of time. The distance AB is the same as that between A_1 and B_1. The changes in pressure are made at each point where an isobar of A or B crosses an isobar of A_1 or B_1, and red lines are drawn for each 0.10-inch fall. It will be found that the maximum change is along a line connecting A_1 and B. Now, if in the example given above, where the distance between the low and the high that precedes it does not change, the pressure rise or fall say 0.20 inch in A and a similar amount in B, then the region of maximum fall will still lie on a line connecting A_1 and B. If, however, the pressure level in A fall 0.20 inch in the assumed time interval during which the low moves to A_1, while the pressure undergoes no change in B, then the maximum fall will be near the center of A_1, as shown by figure 6 (XLIV–39). Should the pressure undergo no change in the high but rise in the low, then the maximum pressure fall will be near the center of the high, B, as shown by figure 7 (XLIV–40). If the pressure level fall in the high, B, while moving to B_1 but does not change in the low, then the maximum fall is also near the position of B, as will be seen by figure 8 (XLIV–41). If the pressure level rise in the high and undergo no change in the low, then the maximum pressure fall is near the center of the low, A_1, as shown by figure 9 (XLIV–42).

In the examples given the distance between the low and the preceding high remained unchanged. If, however, the distance increase or decrease, the maximum pressure fall varies both in amount and position. Thus, in figure 10 (XLIV–43), the high moves faster than the low and the distance between the two at the end of the interval is greater, then the position of the maximum pressure fall is near the center of the high, B. Similarly in figure 11 (XLIV–44), if the low move faster than the high and the distance between the two is less at the end of the interval, the position of the maximum pressure fall is near the center of the low, A_1. The daily pressure-change map will show changes, such as these, that arise from similar movements of and changes in pressure in highs and lows.

Many other examples could be given of how the position of the area of maximum pressure fall varies with the movements of the highs and lows, and some of the results are astonishing. For example, it has been commonly supposed that the area of maximum pressure fall is always in front of and in the line of advance of lows that move rapidly, but it is possible to show that *a low that moves with great speed may have the maximum pressure fall, in the given interval, in its rear. This occurs when the low moves beyond the position occupied by the high at the beginning of the interval, and it is seen occasionally on the weather map.* This is shown by figure 12 (XLIV–45). On this chart the low, A_1, is assumed to have moved from A to beyond the position of the high, B, at the preceding observation, while the high, B, is moving ahead of it. The position of the high, B_1, at the end of the interval is not shown.

Nothing has been said concerning the areas of maximum rise, but it is believed that these can be shown to be dependent, as are the areas of maximum pressure fall, on the changes in intensity, speed, and direction of movement of highs and lows. It follows that the isallobaric charts are but representations of pressure changes that result directly from the movements of and changes of pressure level in highs and lows, and nothing more. It is obvious, however, that the nature of these maximum pressure changes being known, many precepts that will materially aid the forecaster may be found. But it is not the intention of the present writer to consider this phase of the question.

These charts, as stated above, are assumed to represent the ideal types of lows and highs as seen portrayed on the weather maps of the United States with this important difference, that the pressure-gradients here represented as uniform, increase in nature from the high to the low. This natural increase in the pressure-gradient from the high toward the center of the low places the area of maximum presure fall nearer the center of the low and modifies somewhat the configuration of the isallobars. Nevertheless, the rules herein stated hold good in principle for ideal types of highs and lows as shown by weather charts of the United States. The pressure changes resulting from complicated cases of isobars surrounding highs and lows do not make it easy to formulate precepts concerning them. There are, moreover, pressure oscillations, generally small in amount, which take place uniformly and gradually over larger areas and independently of the movement of highs and lows. These oscillations result, in all probability, from changes in the general circulation and are shown first in modifications of the subpermanent areas of high and of low pressure, or the so-called centers of action.

FIRE-WEATHER WARNINGS.

By HENRY E. WILLIAMS, Meteorolgist in charge of Forecast Division.

The following extracts from reports rendered and papers prepared by the district forecasters are published with a view to bringing down to date the available information relating to the fire-weather warning service, as this project is hereafter to be designated. This service was authorized in the Portland and San Francisco forecast districts in the summer of 1913 on the recommendation of District Forecaster E. A. Beals, at the suggestion of officials of the United States Forest Service and the Western Forestry and Conservation Association. Only one or two warnings were issued during 1913, and those for the Portland District. None were issued in the San Francisco District. In 1914 the service was extended to all the other forecast districts, and the reports from these districts show warnings issued as follows:

Fire-weather warnings issued by the several forecast districts during 1913, 1914, and 1915.

Forecast district.	1913	1914	1915
Washington	None.	None.	None.
New Orleans [1]	None.	None.	None.
Denver	None.	None.	1
Chicago	None	6	5
San Francisco [2]	None.	(?)	(?)
Portland, Oreg.	2	17	8

[1] Warnings only on request of district foresters. [2] Record incomplete.

That these warnings were considered valuable by the interests affected is shown by the following resolution adopted by the Forestry Industry Conference, composed of the Western Forestry and Conservation Association and State, Federal, and British Columbia forest agencies, meeting in San Francisco October 19 and 20, 1915:

> The usefulness of the United States Weather Bureau in forecasting dangerous fire weather is no longer open to question. Trial has demonstrated that adequate provision of men and instruments to perfect the system will do much more to prevent fire losses than any other possible expenditure of the small sum needed, say $10,000 annually. No one else can do this work and we appeal to Congress to provide for it. The public values that it will protect are tremendously greater and slower of recovery, if destroyed, than any other which the Weather Bureau now safeguards.

In view of the reasonable success of these warnings during the past three years, a period of informal study and preparation, the Chief of the Weather Bureau feels justified in making the fire-weather warnings service a recognized branch of Weather Bureau activity. Accordingly, formal instructions (Instructions No. 26) were issued on April 10, 1916, wherein—

> District forecasters are authorized to issue warnings, to be known as "fire-weather warnings," of conditions favorable for the inception of fires in the forested regions of their respective districts. * * *

Portland, Oreg., District.[1]—Referring to letter of November 16, 1915, from the Chief of the Forecast Division relative to the number of fire-weather forecasts that have been issued from this district for the seasons of 1914 and 1915, I beg to inclose copies of each, which number 17 in 1914 and 8 in 1915, or 25 in all.

These forecasts, so far as practicable, are made in sets, or, in other words, when hot weather or increasing winds are expected, a forecast is made, and followed each day by another showing such modifications as may be necessary, until a forecast can be made of the termination of the dangerous conditions. By counting the forecasts after the foregoing plan, seven sets were issued in 1914 and three in 1915.

So far as the benefits are concerned I wish to state that I have been informed by the chief wardens of some of the forest fire associations that they were of help to them, and their letters in this connection were promptly forwarded at the time to the central office. Also at the last two conventions of the Western Forestry and Conservation Association, both of which I attended, the sentiment of those present was strongly in favor of continuing this work. At the last convention a resolution was passed calling upon Congress to appropriate the sum of $10,000 to be applied in strengthening the service.—*E. A. Beals.*

San Francisco District.[2]—I regret to report that I am unable to give either the number of times during 1914 and 1915 or the dates on which the Forest Service was advised to expect fire winds, or what is nearly as important, very hot spells of weather, as these greatly add to the activity of a forest fire.

Whenever either of these conditions is expected, the plan has been to call up the district forester by telephone and outline the condition expected and in what portion of the State it will occur. The forester then notifies his supervisors and they issue the necessary instructions and make preparations to meet the condition indicated.

The seasons of both 1914 and 1915 were remarkably free from fire winds or very hot spells of weather. This was especially the case during the past summer.

This work is in its infancy, and our efforts, while in a great measure satisfactory, have been conducted along the broadest lines, because the problem is a new one with many angles and possibilities of which we know but little. What we need is reliable and complete wind data from the forests for study and first-hand field experience. At present our daily weather maps give us the necessary information for a general forecast covering large areas. This is not satisfactory. Our problem is one of great detail and the details must be worked out. The forests are in the mountains where the wind directions and in a great measure the velocities are controlled by the topography of the country, and we can not hope to be in a position to apply the forecasts to specific localities until these are understood.

From our present knowledge of this work, there appear to be two things that should be done at once:

(*a*) Get records of wind velocities and directions from a number of selected ranger lookout stations at different elevations in each forest for study in conjunction with the daily forecast charts.

(*b*) Active and energetic men, one in each forecast district, for field service under the direction of the district forecaster. They should be thoroughly practical, and after carefully studying the methods used by the Forest Service in fighting fires and the effect of different kinds of weather upon the spreading of fires, they should be capable of devising means for closer and more effective cooperation between the Forest Service and the Weather Bureau for the prosecution of this important work.

The diurnal range of temperature in the mountains is considerable, and it is a well-known fact that at night, when the temperature approximates the dew point and the relative humidity is high, forest fires lose much of their energy. But for the same reason, successful backfiring on nights when the humidity is very high is almost impossible owing to the difficulty in getting them to burn. We should be able to advise the district forester when such conditions are probable; then, if his men reach the fire line after the temperature has begun to fall, he can allow them to rest up and be fresh for effective fire fighting the next morning; otherwise they will be tired and worn out by ineffective work during the night and not able to keep up the work at the most critical time.

During the past season we have made an attempt to gather some data of wind velocities in the forests in this district by placing five anemometers at lookout stations across the northern part of the State in the Klamath and Shasta National Forests at Dry Lake, Orleans Mountain, Mount Eddy, Grizzly Peak, and Sisson. (Map showing locations of the above stations forwarded to the central office with letter of July 30, 1915.) Unfortunately we were not able to equip them with self-registers, and therefore much valuable detailed data will not be available for study. However, the rangers were instructed to make dial readings and note the direction of the wind every three hours during daylight. They were also instructed in case the wind changed to a northerly direction and increased in force to telephone the facts to the supervisor at Sisson, which was selected as the "key" station. By placing one of the anemometers at Sisson, at an elevation of 3,555 feet, and another on Mount Eddy, about 8 miles west, at an elevation of over 9,000 feet, it is hoped that we may be able to correlate the velocities at the higher and lower levels.

I beg to report that this work has received careful consideration not only on the part of this office but also by

[1] Extracts from report by the district forecaster, Portland, Oreg., of Nov. 26, 1915.
[2] Extracts from reports by the district forecaster, San Francisco, Cal., of Nov. 29, 1915, and Feb. 23, 1916.

consultations with the district forester and the several supervisors in this district. There are many factors deserving of careful study and investigation which are conducive to starting forest fires and also to aggravating a fire already started.

The condition of the humus on the forest floor is a matter of vital import. No serious fire may be expected until after it has become quite dry, and probably the rate of evaporation at the surface is proportional to the fire hazard. Assuming this, we must next determine what meteorological factors can be safely taken as an index for the rapid drying of the forest floor. These, I believe, can safely be reduced to two, a drying wind or very warm weather. A north or northeast wind, although light, causes a decided drop in the humidity in California, and consequently a rapid drying of the forest floor; also high temperatures in this State are invariably accompanied by low humidity, causing the same rapid drying condition. If the temperatures are only moderately high, they will have to continue for several days before the humus is sufficiently dry to become dangerous. Any combination of the above-named conditions will be conducive to hastening the drying process and raising the fire hazard.

Once a fire has started, dry winds and warm weather greatly tend to increase its energy, the increase being proportional to the velocity of the wind and intensity of the hot spell. Cloudy weather, particularlly if accompanied by winds coming off the ocean and carrying a high percentage of humidity, are factors that in a marked degree mitigate against the rapid spread of a fire. A shower of 0.25 inch will, in nearly every case, bring a fire under perfect control, and in many cases even 0.10 inch will so reduce a fire's energy that it can be easily handled.

From the forester's standpoint there are other serious factors to be considered, among which are the character of the undergrowth and its density, the topography of the country and the availability of men for emergency service and their transportation to the fire zone. His fire hazard also increases as the number of people frequenting the forests increases, and from many other causes.

In addition to the information shown on the weather map and from special observations, whenever a ranger on lookout duty stationed on some high peak, observes the wind to be blowing from the north or northeast at a rate of 10 miles per hour for one hour, he telephones the supervisor to that effect, and if two such reports are received, the supervisor immediately telephones the district forester's office in this city, and he in turn notifies the district forecaster. If it is decided to issue a fire warning, the district forester is advised of the necessity for such warning, given the forecast and the sections to which it applies. The forester then distributes the warning to his supervisors, who in turn telephone it to all rangers and make preparations for any emergency that may arise.—*G. H. Willson.*

Chicago, Ill., District.[3]—In 1914 six warnings were sent to northern Minnesota and one to western Montana.

In 1915 five warnings were sent to northern Minnesota, all during the month of June. At the request of the section director at Minneapolis messages, even for moderate breezes, were sent to the foresters during the critical season in June.

"Fire-wind" warnings have not been issued to any great extent during the past two seasons to the States in this district listed for them, viz, northern Minnesota, western South Dakota, Montana, and Wyoming. This is partly due to the absence of deep lows or strong winds during the critical season, and to more than the usual rainfall, especially in 1915. The messages have been sent during the periods specified by the section directors, being discontinued upon their telegraphic request.

I have no information upon the subject of benefits from the warnings issued.—*H. J. Cox.*

[3] Extracts from report by the district forecaster, Chicago, Ill., of Nov. 23, 1915.

551.5?4.3?

DROUGHTS AND HOT WEATHER.[4]

By E. A. BEALS, District Forecaster.

[Weather Bureau, Portland, Oreg., December, 1915.]

When the forest litter is wet it is hard to start a forest fire; when dry it is easy, therefore a prerequisite of a forest fire is a drought. Drought has never been defined in definite terms, but the common meaning is long-continued dry weather, especially so long continued as to cause vegetation to wither. Vegetation withers when deprived of moisture, and, while lack of rain is essential, another important factor is evaporation. When evaporation is rapid, the injurious effects of dry weather are intensified, and when it is slow they are mitigated. The amount of evaporation depends on a number of things, the most important of which from a meteorological standpoint are humidity, temperature, wind, and barometric pressure (3).

Evaporation is accelerated when the humidity and pressure are low and the temperature and wind are high. As there are no means of correctly measuring evaporation from a forest cover, it is necessary to consider the factors causing rapid evaporation in order to determine the extent of the fire danger to which a forest is exposed. Of these factors, which consist of low humidity, low pressure, high temperature, and high wind, the Weather Bureau furnishes the public with predictions of the two most essential, viz, high temperatures and high winds.

Of the remaining factors, that of low pressure exerts a minor influence on evaporation, and while not specifically included in the forecasts, the areas of low pressure are usually described in the notes accompanying weather maps, and the maps show their location as well. When fire-weather forecasts are made, the locations and movements of both the low and high pressure areas are included in each forecast.

No attempt has been made to predict humidity, but it is understood by the public on the Pacific slope that when hot weather prevails the humidity will be low, and a prediction of hot weather during a drought practically covers both elements.

HIGH WINDS.

High winds in combination with drought cause far greater losses through their influence in fanning the flames than in their effect on evaporation, therefore they should be treated separately, which leaves high temperatures during droughty periods as one of the principal elements requiring attention when making predictions of weather favorable to an increase of forest fires.

Should the wind increase to a moderate breeze, or stronger, as defined by the Beaufort scale, it is almost impossible to extinguish a forest fire. Moderately high winds from any direction are dreaded by forest-fire fighters, but in the Pacific States those from an easterly direction are dreaded more than those from any other direction, as they are invariably parching winds that sap the vitality of the trees, and rapidly dry out the leaf litter and duff.

[4] Extracts from paper, "Forecasts of weather favorable to the increase of forest fires," read before the Pan-American Scientific Congress at Washington, D. C., Dec. 30, 1915.