Potsdam [53] show, respectively, 40 and 50 per cent of the iridescence observations to have been on cirro-cumuli, as against 24 and 20 per cent on alto-cumuli, while Ci., Ci.-St., and Ci.-Cu. grouped together include 58 and 78 per cent of the cases. In my own observations I have credited cirro-cumuli with only 7 per cent, and alto-cumuli with 45, while Ci., Ci.-St., and Ci.-Cu. together comprise only 11 per cent of the total occurrences of iridescence. Cirro-cumulus and cirro-stratus may feature too seldom in these observations, even though I faithfully attempted to keep strictly to the current International definitions.[54]

We should not forget the fundamental basis of height in our International cloud forms. Therefore, as originally intended,[55] all reasonable care should be exercised to reserve the names cirro-stratus and cirro-cumulus for clouds that are distinctly higher than alto-stratus and alto-cumulus. Thinness and small apparent size of elements in the higher clouds are primary criteria, but the thin and small-size initial phases of the lower ones should not lead the observer to misname them with the names of the higher. The occurrence and angular extent of iridescence seems to provide a hitherto unused aid in differentiating what might be called pseudo-cirro-stratus and cirro-cumulus, which are really alto-stratus and alto cumulus ("* * * finer flakes (resembling Ci.-Cu.)"),[56] from the true and higher types.

*Conclusion*.—The apparent value of the extent of iridescence as a rough index to temperature, and, therefore, to approximate cloud height, should justify, (1) the regular use of dark glasses by observers, (2) the rough angular measurement of the radii of coronas and the extent of iridescence, and (3) the entry of such observations as an essential part of the cloud record. Furthermore, systematic observations of the heights and temperatures of iridescent clouds should be undertaken at aerological stations, in order to establish the degree to which angular extent of iridescence on different cloud types forming at different rates may be used as an indication of cloud temperature and height.

## USING WEATHER FORECASTS FOR PREDICTING FOREST-FIRE DANGER

By H. T. GISBORNE, U. S. Forest Service

[Priest River Experiment Station]

Three kinds of weather control the fluctuations of forest-fire danger—wet weather, dry weather, and windy weather. Two other conditions also contribute to the fluctuation of fire danger. These are the occurrence of lightning and the activities of man. But neither of these fire-starting agencies is fully effective unless the weather has dried out the forest materials so they are dry enough to burn.

Forest fires can not be started and will not spread unless the forest fuels are dry. Wet weather makes the fuels wet, dry weather makes them inflammable, windy weather fans the flames and makes the fires most difficult to control. If the degree of wetness, dryness, and windiness of the weather can be forecast accurately in time and place, fire danger can likewise be forecast with sufficient accuracy to improve very greatly the efficiency of forest-fire detection and suppression. The purpose of the present article is to illustrate some of the detailed procedures involved in the process of translating weather forecasts into fire-danger forecasts for the conifer timber types of northern Idaho and western Montana.

Investigations of the relation of weather to fire danger were initiated in this region by the Priest River Forest Experiment Station in 1916. These first researches were largely devoted to the compilation and comparison of records of weather and forest fires. The report, "Climate and Forest Fires in Montana and Northern Idaho, 1909 to 1919,"[1] by Larsen and Delavan, gives specific data on both weather and fire fluctuations. The present object of fire studies, however, is to make available to the fire-fighting organization all possible information concerning present and probable fire danger so that that organization may expand to meet increasing danger and contract to save unnecessary expense whenever possible.

A forecast of several days of hot, dry weather does not always mean a certain degree of fire danger in this region. The effect of that hot, dry weather depends on how wet the fuels were to begin with. If it has rained recently, a week or more of drying weather may be required before extreme danger will result. Likewise, *following a drought, the forecast may be for a period of* high humidity, or rain, and the effect will depend on how dry the fuels were to begin with, as well as on how high the humidity may be or how much rain may fall. Before weather forecasts can be used accurately in determining what protective action should be taken, it is necessary to know the prevailing moisture contents of the various fuels.

Studies at the Priest River Forest Experiment Station in northern Idaho have shown that the top layer of duff (decaying leaves and twigs covering the mineral soil) responds to weather changes about as the average of all the combustible forest materials, from moss, weeds, and twigs, to slash and the outside wood on windfalls and snags. The finer and lighter of these fuels pick up and lose moisture rapidly; the heavier fuels, such as branchwood, etc., respond more slowly. The top layer of duff seems to be a reliable criterion of the average response.

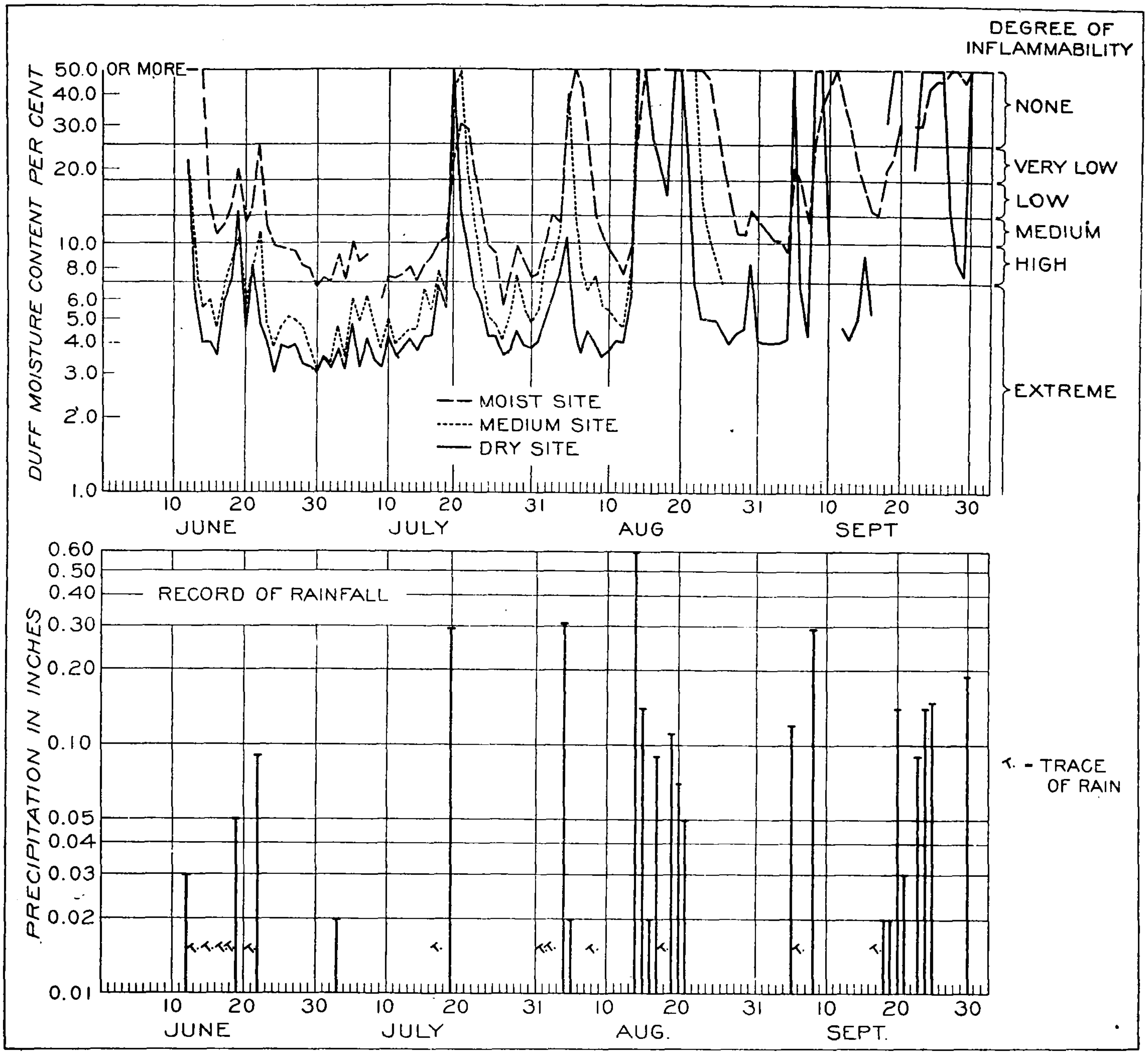
An instrument for measuring the prevailing moisture content in that top layer of duff, called a duff hygrometer, has been invented by the U. S. Forest Products Laboratory and the Priest River Station. Numerous tests of the inflammability of duff in relation to its moisture content have permitted the delineation of six zones of inflammability—none, very low, low, medium, high, and extreme. By this means it is possible to apply weather forecasts to a reliable base and so obtain a translation into terms of fire danger. Past practice has shown that such a translation can not be made with sufficient accuracy without such a base to build on.

During the past fire season (1924) three duff hygrometers were used to measure prevailing duff moisture contents on three different sites in the vicinity of the Priest River Forest Experiment Station in northern Idaho. These three sites may be termed, (1) moist site, a fully timbered northwest slope; (2) medium site, a partially cut-over knoll top; (3) dry site, a clean-cut, fully exposed flat. Figure 1 shows the fluctuations of moisture content recorded, also the various zones of inflammability, as previously described.

As might be expected, these three sites, all within a circle less than a mile in diameter, generally exhibited very different degrees of fire danger, the fully timbered station usually showing the most moisture, the clean-cut area the least, and the partially cut area an intermediate amount. Table 1 shows the percentage of time during which each site experienced the various degrees of inflammability.

[53] Arendt, op. cit., p. 223.
[54] International Cloud Atlas, Paris, 1910.
[55] Cf. Brooks, op. cit.
[56] International Cloud Atlas, Paris, 1910. Part of designation of alto-cumulus.

[1] MO. WEATHER REV., Feb., 1922, 50: 55–68.




INFLAMMABILITY OF FOREST DUFF
Three Sites at Priest River Forest Experiment Station.

FIG. 1.—Relation between the distribution of rainfall and the inflammability of forest duff during the fire season of 1924 near Priest River Forest Experiment Station, Idaho

TABLE 1.—*Percentage of time (June 12 to August 30, inclusive) on which various degrees of inflammability occurred*

| Inflammability | Extreme | Extreme and high | Extreme, high, and medium | Extreme, high, medium, and low | Extreme, high, medium, low, and very low | None |
|---|---|---|---|---|---|---|
| Dry site | 76 | 83 | 86 | 89 | 93 | 7 |
| Medium site | 57 | 74 | 79 | 83 | 85 | 15 |
| Moist site | 5 | 43 | 59 | 68 | 75 | 25 |
| Average | 46 | 67 | 75 | 80 | 84 | 16 |

From the chart and the table it is evident that both the daily fluctuations and the average inflammabilities on these sites differed considerably, yet the same weather passed over all of them. The fallacy of using measurements of prevailing weather alone as an index of existing fire danger is consequently apparent, if the region contains any variety of topography and timber types. Likewise, a weather forecast which means one degree of danger for one site may mean an entirely different degree on another site.

Each evening from June 30 to September 20, at 5 or 5:30 p. m., when the duff hygrometers had been read and the prevailing conditions plotted on the current chart, a forecast was written down to show the degree of inflammability to be expected on each site 24 hours later. This forecast utilized the zones of inflammability shown in Figure 1, and the U. S. Weather Bureau forecast received that morning covering the following 36 hours. These inflammability forecasts have been rated to determine their dependability. Whenever the point actually fell in the zone predicted, the forecast was rated as 100 per cent accurate. If the point fell in the first zone above or below the one predicted, the forecast was given a rating of 75 per cent. If the point plotted in the second zone, above or below, the forecast was rated at 50 per cent; if in the third zone, 25 per cent; and if in the fourth or fifth zones, zero per cent. The results were as follows:

| | | |
|---|---|---|
| Dry site | 76 forecasts, | 82 per cent dependable. |
| Medium site | 55 forecasts, | 85 per cent dependable. |
| Moist site | 78 forecasts, | 88 per cent dependable. |
| Total | 209 forecasts, | 86 per cent dependable. |

All of the serious errors, producing zero ratings, occurred when the forecasts for the dry site were framed on the following dates: June 30, July 1, 18, 21, 27, August 13, September 4 and 7. These dates also produced errors, though not all serious, for both the other sites. It is well to point out the conditions which produced the serious errors in forecasting for the dry site, which is the most difficult because it responds most rapidly to changes in the weather.

1. On June 30 the special weather forecast for north Idaho read: "Becoming unsettled. Probably thunderstorms in the mountains tonight and Tuesday * * *." Local conditions substantiated this forecast and a prediction of no inflammability was consequently written for the dry site on the assumption that there would be some rain. The thunderstorms did not materialize, there was no rain, and the inflammability was found to be extreme 24 hours later.

2. On July 1 the weather forecast read: "Hot weather through to-day, will be followed by slightly lower temperatures to-night and Wednesday with thunderstorms in mountains this afternoon * * *." The thunderstorms had not occurred but still seemed probable and a compromise forecast of "High or lower" was written for July 2. It was actually extreme.

3. On July 18 the weather forecast read: "Generally cloudy weather with moderate temperatures through to-night and Saturday with slight possibility of local showers * * *." Local conditions did not seem to favor the "slight possibility of local showers" and a forecast of extreme inflammability was therefore written. A rain of 0.29 inch between 8:30 a. m. and 3:00 p. m. on the 19th resulted in no inflammability.

4. On July 21, contrary to a "fair weather" forecast by the Weather Bureau, but using as a basis the local measurements of pressure, temperature, humidity, and wind direction, a prediction of no inflammability was written. Actually it was extreme.

5. On July 27 the official forecast read: "Cloudy, probably showers to-night and Monday, with thunderstorms in the mountains." No inflammability was forecast; actually it was extreme.

6. On August 13 the weather forecast read: "Showers and cooler to-night and Thursday, probably thunderstorms in mountains." Because of a slightly higher local barometer, a forecast of extreme inflammability was written. Rain amounting to 0.60 inch between 5:30 a. m. and 3:00 p. m. the 14th produced a condition of no inflammability, however.

7. On September 4 the official forecast read: "Fair weather, moderately warm, low humidity * * *." A prediction of extreme inflammability was written, but 0.12 inch of rain between 1:30 a. m. and 1:45 p. m. on the 5th caused no inflammability that evening.

8. On September 7 the weather forecast read: "Fair to-night and Monday, continued warm." Extreme inflammability was predicted, even in the face of a rapidly falling barometer. Rain amounting to 0.29 inch between 5:30 a. m. and 1:30 p. m. on the 8th produced no inflammability.

From these eight cases of absolute failures it is evident that "to rain or not to rain" is the vital question in this region. The chart shows that none of the curves rose to "Very low" or "No inflammability" except when pushed there by precipitation. Changes in other weather elements such as temperature or humidity, while very important, never produced differences in inflammability sufficient to cause serious errors in forecasting fire danger as determined by dryness of fuels. Rain is recognized as the single weather element which can produce a complete cessation of fire danger in this region, and whenever this weather element can be forecast with high dependability large sums of money can be saved in the handling of existing fires.

From these preliminary indications it appears that we are already able to predict the degree of dryness of forest fire fuels with a very satisfactory percentage of dependability. Three features stand out as desirable—first, the official weather forecasts should be strictly adhered to, and local weather conditions should not be given too much weight; second, the period covered by the fire-danger forecast should be lengthened as much as possible; third, predictions of rain or no rain will be more valuable if given with more assurance. An attempt will be made at Priest River Experiment Station to lengthen the period to include 36 instead of 24 hours next year, and it is hoped and expected that the Weather Bureau will name our rainy days even more successfully next year than last. Four additional duff hygrometers will also be installed next season in average sites at four new stations in various parts of western Montana and northern Idaho so that the Weather Bureau forecasts may be utilized more intensively. With increased experience in interpreting the effects of weather on the fuel moisture contents, it is expected that our present percentage of accuracy, which is already satisfactory, can be increased materially.

## THE FOREST-FIRE SEASON AT DIFFERENT ELEVATIONS IN IDAHO

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In any fire-ridden forest region, such as north Idaho, there is great need for a tangible basis by which to judge the length and the intensity of the fire season in different forest types and at different elevations. The major and natural forest types, such as the western yellow-pine forests, the western white-pine forests, and the subalpine forests occur in altitudinal zonations one above the other and are the result of differences in air temperature and precipitation which affect not only life, growth, and distribution, but the fire hazard as well. It follows, therefore, that in addition to the local and physical