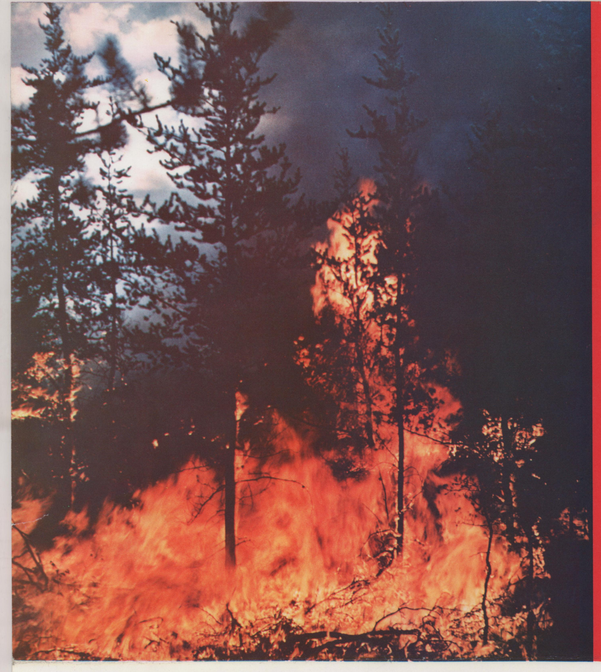

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Forest Fire Weather Zones of Canada

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FOREST FIRE WEATHER ZONES OF CANADA

A. J. Simard*

INTRODUCTION

Wildland fires are controlled by two basic factors: the vagaries of their environment and the activities of man. Man is primarily responsible for the two extreme ends of the wildfire spectrum. He starts and extinguishes most of the wildland fires which occur. Between the extremes, the environment predominates. The environment consists of three basic factors: fuels, topography and weather. Fuels determine the quantity of material potentially available for combustion, while topography primarily affects rate of spread. Weather determines the characteristics of fire behavior as well as influencing the quantity of fuel which will burn. While an understanding of the complex interactions between these three factors has increased considerably in the past decade, a great deal remains to be learned.

There is little doubt that weather is by far the most important of the environment factors. Given a constant weather pattern, the range of fire behavior characteristics for all forest fuel types and topographies is not likely to be much greater than a factor of ten. Given a fixed forest fuel type and topography, weather changes can cause changes in fire behavior characteristics on the order of a thousand times.

If one considers only the effects of weather on fire behavior, the fire control manager is still faced with the task of interpreting a complex set of relationships. Several variables are involved simultaneously and all are involved in more than one aspect of fire behavior. For this reason a Fire Weather Index (FWI), (C.F.S., 1970), was developed that integrates the combined effects of the four most important weather parameters into a set of codes and indices culminating in a single number which can be used as a relative measure of expected fire intensity.

The FWI has a wide variety of day-to-day and long-term uses. One long-term use would be comparison of relative fire weather severity between two or more regions to aid presuppression planning. This map and discussion provides background information for such planning by plotting and describing the seasonal FWI patterns for Canada. When this information (or similar information in greater detail) is coupled with other necessary presuppression information such as fuels, topography and values-at-risk, a solid foundation upon which to base meaningful decisions is formed.

DISCUSSION

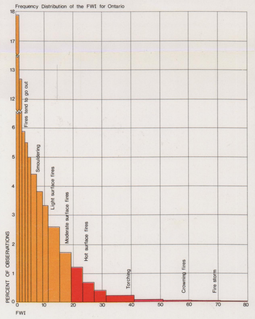
The Forest Fire Research Institute recently established a data bank containing, among other parameters, daily weather observations required for calculating the Canadian Forest Fire Weather Index. In essence, data from 1957 to 1966 for the period April 1 to October 31 has been acquired for 364 stations in the forested regions of Canada. As the data was acquired it was processed through a series of computer programs, one of which calculated the FWI as well as each code and index of which it is composed. Further computer processing yielded a distribution of each of the codes and indices by month, year and station. The above procedures are described in detail by Simard (1972), and Simard and Valenzuela (1972).

With this set of historical data available it is possible to plot a considerable number of fire weather patterns for Canada. Average or extreme seasonal values could be plotted for any of the six codes or indices of which the FWI is composed. Alternatively, a series of monthly or even bi-weekly patterns of any of the above could also be plotted. Another useful pattern display would be the severity index (Williams, 1959) as adapted to the FWI by Van Wagner (1970). In addition, various duration measurements could be useful, such as season start, length or end, number of days above certain predetermined values, etc. To date, two areal patterns based on the new index have been plotted. Jackson (1968) plotted drought index patterns for British Columbia. Stocks (1971) plotted short-term and yearly severity index patterns for Ontario.

Plotting all possible combinations of patterns would be a considerable undertaking. It was decided that only a single index would be plotted with the purpose of yielding an overall seasonal fire weather pattern for Canada. This immediately limits the choice of relevant items to average FWI, and the severity index.

As pointed out by Stocks, if the FWI were bimodally distributed, use of an average FWI would not yield a true measure of the difficulties likely to be encountered. A season composed primarily of low and extreme days is considered to be worse than one composed primarily of moderate days, although the average FWI would be the same in both cases. As sample size increases, the probability of distributional variability decreases. For example, examination of Fig. 1, which is based on 94,000 observations in the province of Ontario, indicates that there is only a single peak to the distribution. In such a case, plotting either average FWI or severity index would yield approximately the same pattern, although the actual numbers would, of course, differ. Since the average FWI is directly available from the previously completed distributional analysis and since a 10-year sample of data is available for each station (with a sample size ranging from 1,000 to 2,000 observations per station) the average FWI was considered to be a valid measure of the distribution of the individual index values. On the other hand, for more specific comparisons of shorter periods such as individual seasons or portions thereof, the severity index may yield somewhat more accurate results.

FIGURE 1



To avoid potential sources of error due to a computer generated start and end of each fire season, average values of the FWI for June, July and August were used. While some regions experience dry weather in May, this was considered too early for many stations. In addition, the May and August FWI values for many of the above stations were approximately equal. Therefore, the average FWI for June, July and August was considered representative of the relative fire weather severity which is likely to be encountered.

Preparation of the map was a fairly straightforward process. The average FWI for each station was plotted on a map of Canada. Iso-index lines were then drawn, at intervals of 2 FWI units. Lastly, seven weather zones based on an approximately geometric progression of the FWI were delineated.

RESULTS

The average FWI values range from a low of 1 to a high of 34, indicating a considerable range of fire weather severity across the country.

In general, fire weather severity, as measured by the average FWI, is highest in southern and western Canada, and lowest in eastern and northern Canada.

As is indicated by the map, seven forest fire weather zones have been defined: 1-Minimal, 2-Very Low, 3-Low, 4-Moderate, 5-High, 6-Very High, and 7-Extreme. Within each zone, a range of weather and FWI values will be experienced. The basic difference between the zones is reflected in variations in the percentage of days on which specific FWI values will be observed. Alternatively, if the percentage of days of interest is fixed (such as the highest 3%) then the zones differ by the expected FWI values observed on that percentage of days.

A set of typical FWI distributions likely to be encountered in the center of each zone is presented in Table 1. For the percentage of days listed in the left-hand column of Table 1 the observed FWI will be equal to or less than the corresponding value listed in the table.

TABLE 1

Average seasonal percentage distributions of the FWI for each Fire Weather Zone

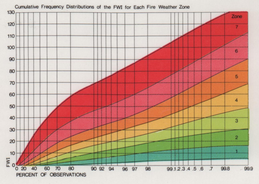
Percent of observations	FIRE WEATHER ZONE 1	2	3	4	5	6	7
	Expected FWI values						
5	0	0	0	0	0	0	0
10	0	0	0	0	0	1	2
15	0	0	0	0	0	2	4
20	0	0	0	0	1	3	6
25	0	0	0	1	1	5	8
30	0	0	0	1	2	7	10
35	0	0	0	2	3	9	14
40	0	0	1	2	4	11	18
45	0	1	1	3	6	13	21
50	0	1	1	4	8	15	24
55	0	1	2	6	9	17	28
60	0	2	3	8	11	19	32
65	0	2	4	10	13	21	36
70	1	3	6	11	15	23	40
75	1	4	7	12	17	25	44
80	1	5	9	14	20	28	48
85	2	7	11	17	24	33	52
90	3	9	14	21	28	38	58
95	5	12	18	26	34	44	65
97	7	15	22	30	39	50	77
99	9	19	29	39	50	67	90
100	12	24	40	60	80	105	125

Approximate lower limit of surface fires

Approximate upper limit of surface fires

For example, in Zone 4 (Moderate) the observed FWI will be equal to or less than 12 on 75% of the days. Conversely, and perhaps of greater significance, the observed FWI will exceed 12 on 25% of the days. The probability distributions listed in Table 1 are presented graphically in Fig. 2.

FIGURE 2



While all zones contain a range of values, the differences between the distributions is quite pronounced. For example, in Zone 1 (average FWI = 1), only 5% of the observations will be greater than 5, while in Zone 7 (average FWI = 25), 80% of the observations will be greater than 5. Two points should be emphasized with respect to Table 1. The first is that the distributions are an average. Observed annual distributions will vary somewhat about this average from year to year and station to station. The second major point is that these observations are based on a 10-year sample of data. While such a sample can be considered adequate, it is by no means all encompassing. It is to be expected that an observed annual distribution will be significantly different from the average if only at infrequent intervals.

If it is assumed that the FWI is an accurate indicator of expected fire intensity in a standard fuel complex, it is possible to quantitatively determine the significance of the various distributions. Using a relationship given by Van Wagner[1]:

$$I = 2.686\, e^{(\ln FWI)^{1.546}}$$

fire intensity was calculated as a function of the FWI. Table 2 lists fire behavior descriptions given by Van Wagner (1968), combined with intensity values calculated from the above equation. It should be used only as a rough guide, as individual observations can vary considerably from the relationships presented in Table 2.

Two boundaries are drawn through Table 1, the lower and upper FWI limits which are likely to be associated with surface fires. Below the lower line, only a minimal suppression effort will likely ever be needed, while above the upper line, every fire is potentially uncontrollable. Between these two boundaries lies what might be considered a normal operating range for an average fire suppression organization. It is now possible to quantitatively describe the average fire weather characteristics of each zone. The quantitative descriptions which follow should not be interpreted as absolute limits however, but rather simply as an indication of average fire weather conditions in each zone.

TABLE 2

Relationship Between the FWI and Expected Fire Behavior in a Standard Fuel Complex[1]

FWI	Intensity[2] (btu/sec. ft.)	Potential Fire Behavior[2]
0 - 4	0 - 7.5	Fires tend to go out by themselves.
5 - 9	7.5 - 25	Fires continue to smoulder.
10 - 14	25 - 75	Light surface fires.
15 - 21	75 - 250	Moderate surface fires.
22 - 31	250 - 750	Hot surface fires.
32 - 47	750 - 2,500	Torching out (individual crowns consumed)
48 - 66	2,500 - 7,500	Crown fires.
67 +	7,500	Conflagrations, fire storms.

THE FOREST FIRE WEATHER ZONES

Zone 1 Minimal (Average FWI = 0 to 2)

Only a small portion of the forested area of Canada lies within this zone. It is restricted entirely to coastal regions. Approximately 65% of the FWI observations will be zero. Little or no control efforts are likely to be required for fires occuring on these days. About 34% of the days will require some, if only minimal control efforts. On only 1% of the days will a sufficient effort to control light surface fires be required. Thus, while forest fire control cannot be totally ignored in this zone it will certainly be a relatively minor undertaking.

Zone 2 Very Low (Average FWI = 2 to 4)

Generally, this zone is located immediately inland from Zone 1 and along the northern limit of the tree line. The percentage of days on which fires require little or no control effort drops to 40% while the proportion of days requiring only minimal control rises to 50%. On 7% of the days the fire control organization will probably encounter light surface fires. In addition, on 3% of the days surface fires are likely to be of moderate intensity, with an occasional hot surface fire occurring.

Zone 3 Low (Average FWI = 4 to 6)

The major areas of Zone 3 are close to the northern limits of the forested area and in eastern Canada. Every province has some area in this zone. On 35% of the days little or no fire control efforts will be needed while on an additional 45% minimal control efforts will be sufficient. On 15% of the days, light to moderate intensity surface fires are likely to be encountered. The major difference between Zone 2 and 3 is that on 4% of the days in Zone 3 hot surface fires can occur and on about 1% of the days, torching out may be encountered.

Zone 4 Moderate (Average FWI = 6 to 10)

This is the most widely distributed zone in Canada. It is found in every province. The largest areas are in western Canada. Zone 4 can be considered the normal or average forest fire weather zone in Canada. The full range of intensities can be expected to occur with some degree of regularity in this zone. One major difference between Zone 4 and the previous zones is that on only 20% of the days will fires require little or no control efforts. An additional 40% of the days will require only minimal control efforts. On 20% of the days light surface fires are likely to be encountered, while on 17% of the days surface fires will be of moderate to hot intensity. A second major difference between this and previous zones is that on 3% of the days torching out and occasional crown fires can occur. The latter may be potentially uncontrollable during daylight hours (depending on the fuel complex). This latter condition is likely to be reached for brief periods once every few years rather than on one or two days every year.

Zone 5 High (Average FWI = 10 to 14)

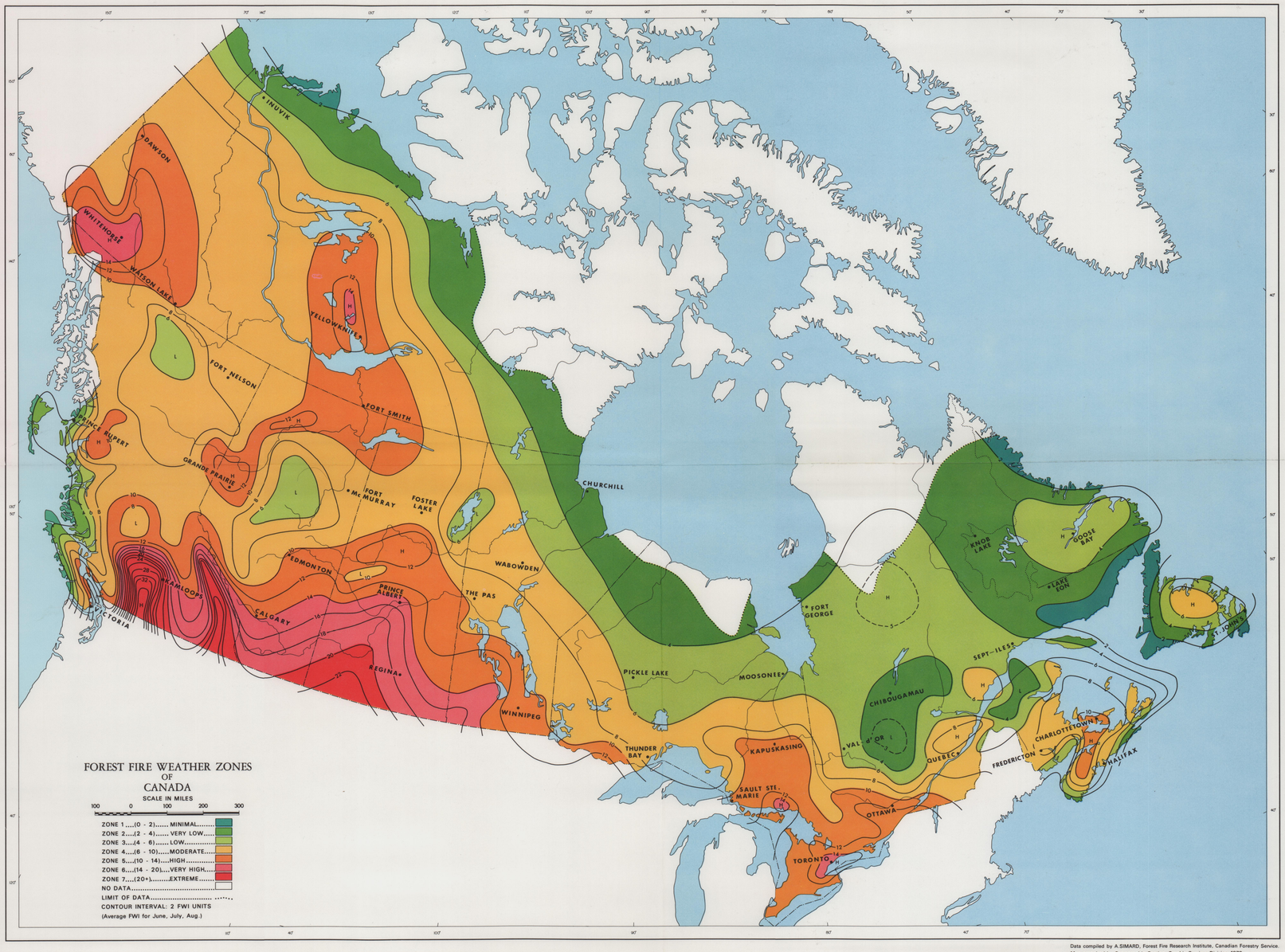
This zone is found primarily in western and southern Canada. The percentage of days on which fires will require little or no control efforts drops slightly to 15% while the proportion of days requiring minimal control remains at 40%. The percentage of days with light surface fires drops slightly to 10% while days with moderate and hot surface fires rises to 25%. Torching out may occur on 7% of the days. The major difference between Zone 5 and 4 is that in Zone 5 on 3% of the days fires will be potentially uncontrollable with occasional conflagrations and fire storms developing. These intensity levels are likely to be reached or at least approached in a majority of fire seasons.

Zone 6 Very High (Average FWI = 14 to 20)

This zone is primarily found in southwestern Canada. While the map indicates that much of the Prairies lies in Zone 6, forest fires are of little consequence in the Prairies due to the lack of forest fuels. The small percentage of days requiring little or no control efforts (5%) precludes such an operational policy inasmuch as fires not contained quickly on such days could become problems as the FWI will quickly climb back to higher values. Minimal control efforts will be needed on 30% of the days. This zone contains the highest percentage of days in the surface fire class – 45%. Of this total, 10% of the days will have light fires, 20% moderate and 15% hot. Torching out may occur on 15% of the days. The percentage of days with potentially uncontrollable fires increases to 5%.

Zone 7 Extreme (Average FWI = 20+)

The significant portions of this zone are limited to two areas in southern British Columbia. Virtually no days are free from a need for some fire control efforts, and only on 25% of the days will a minimum effort be sufficient. The proportion of days with surface fires drops to 30% while days when torching out may occur increases to 20%. The main difference between Zones 6 and 7 is that the percentage of days with potentially uncontrollable fires jumps to 25% in Zone 7. Few, if any fire seasons will not have the latter type of days and they will probably last for extended periods. Forest fire control will be a major or at least very important proportion of the total forestry activity in these regions. It is in this zone that absolute FWI extremes are likely to occur. The highest value recorded between 1957 and 1966 was 153 at Kimberly in southeastern British Columbia.



FOREST FIRE WEATHER ZONES OF CANADA

SCALE IN MILES 100 0 100 200 300

ZONE 1....(0 - 2)..... MINIMAL.....
ZONE 2....(2 - 4)..... VERY LOW.....
ZONE 3....(4 - 6)..... LOW.....
ZONE 4....(6 - 10)..... MODERATE.....
ZONE 5....(10 - 14)..... HIGH.....
ZONE 6....(14 - 20)..... VERY HIGH.....
ZONE 7....(20+)..... EXTREME.....
NO DATA.....
LIMIT OF DATA.....
CONTOUR INTERVAL: 2 FWI UNITS
(Average FWI for June, July, Aug.)

Data compiled by A.SIMARD, Forest Fire Research Institute, Canadian Forestry Service.
Map prepared by Cartographic Section, Graphic Services Division. 1973.

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[1] Personal Communication. This is a basic relationship found in the FWI.

[1] A mature pine forest.
[2] After a fire has reached a state of equilibrium.