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POSSIBLE PERIODICITIES IN WEATHER PATTERNS AND CANADIAN FOREST FIRE SEASONS

by

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ABSTRACT

Weather trends have been determined from an analysis of long-term rainfall records for towns in the southern part of Canada. The incidence of forest fires in the provinces correlates well with the approximately periodic "drought patterns" in these areas. Though there are few fire statistics before 1920, it is evident that famous "historic" fires also fit the correlation. It is suggested that the weather (and fire) patterns observed could be connected with the sun-spot cycle.

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INTRODUCTION

The notion of regularities in the occurrence of large fires is not new. More than 30 years ago, Wright (1940) suggested there was a connection between the incidence of forest fires in New Brunswick and the sunspot cycle: and, somewhat later, Boultbee (1961) found evidence of a regular pattern in the occurrence of large rural fires in Ontario.

There are similar beliefs in Australia. In the southeast of that continent there is an apparent pattern of bad fire-years every 6 to 7 years (cf., Vines 1967) and, in fact, since the turn of the century extremely bad fires have been experienced in Victoria every 13 years -- in 1913, 1926, 1939, 1952 and 1965. The fires in the intermediate bad years (1920, 1932, 1944 and 1959) were less devastating. In Western Australia the fire frequency seems to be different, the major fire-seasons having occurred in 1930, 1941, 1950 and 1961, i.e., about every 10 to 11 years.

Since forest fires and drought are intimately associated, an analysis of long-term Canadian rainfall records was undertaken to see if there were any discernable connections between the periodic occurrence of fires and possible periodicities in rainfall. Many towns in the southern part of Canada, from the Maritimes to British Columbia, have long-term rainfall records; thus the analysis covered a wide area. The results are briefly described in this paper.

RAINFALL RECORDS

Tables of yearly rainfall totals were provided by the Canadian Atmospheric Environment Service*. Initially, an intensive study was made of the records for towns in southern Ontario; but when the results appeared promising, other towns in Quebec, the Maritimes, the Prairies and British Columbia were also investigated (see Map, page 2).

So that data for the different centres could be compared, the rainfall totals were entered on punch cards and processed by computer (Univac 1108), using a program which smoothed the

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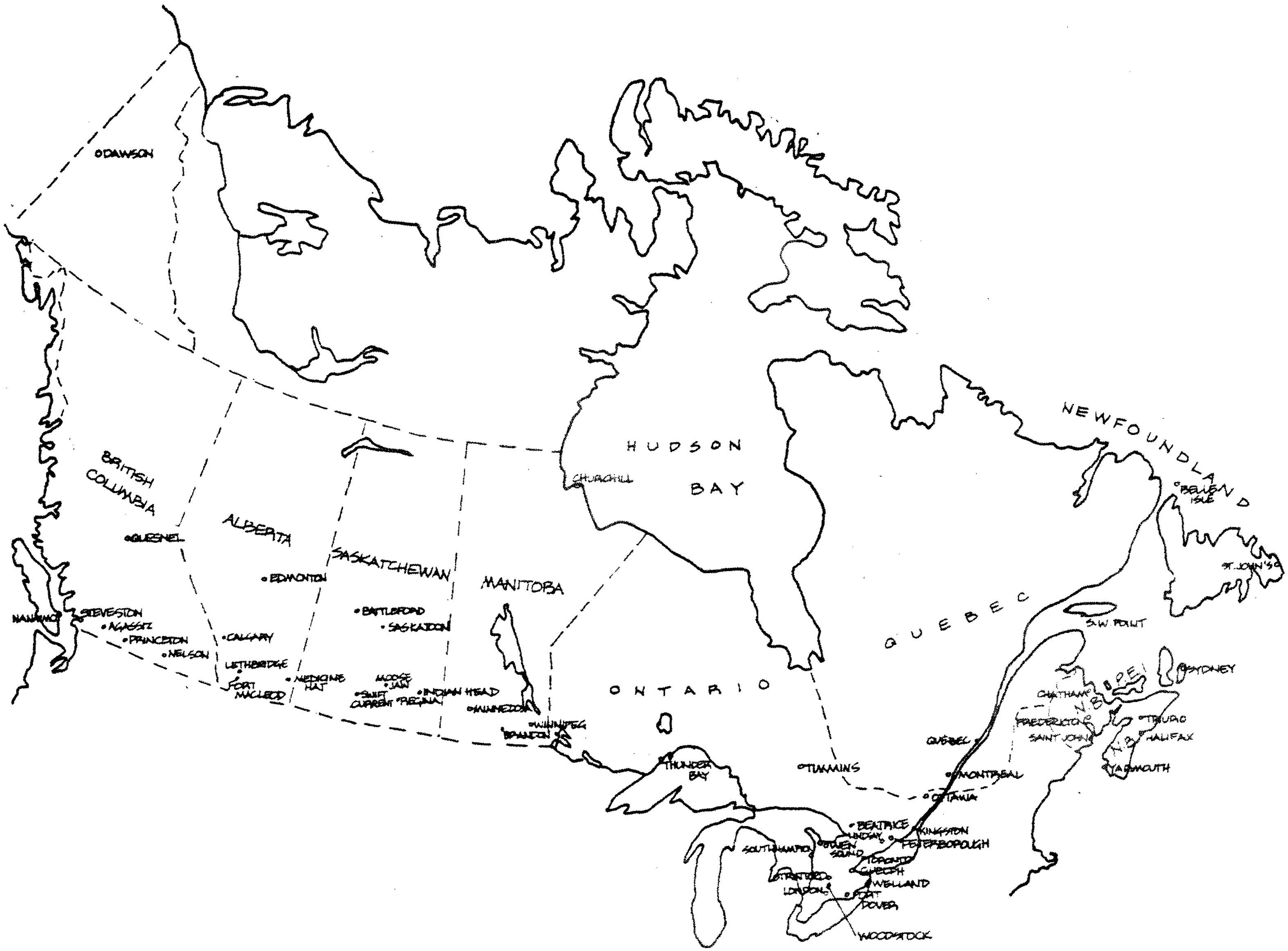
*The records were of variable duration, some extending for less than 50 years, and a few for 100 years, or more (e.g., Toronto records go back to 1846). In the tables supplied there were no measurements after 1967.



MAP SHOWING DISTRIBUTION OF TOWNS STUDIED records and removed short-term fluctuations in the figures. The program is outlined below.

THE COMPUTER PROGRAM

In treating the rainfall records, the program subjects them to 4 filters in combination (cf. Fig. 1), a procedure devised some years ago by Dr. E.G. Bowen of the CSIRO Division of Radiophysics in Australia. Each filter scans the data for periodic rainfall fluctuations over a given frequency range (in years), but rejects all others. Thus Filter I only allows the passage of signals having periods from 5-1/2 to 9 years. Filter II accepts those periods ranging from 7-1/2 to 16 years, while Filter III accepts those from 11 to >50 years. Filter IV accepts all periods beyond 20 years, and it therefore reproduces what is essentially a shifting-mean-rainfall. The total filter system is represented diagrammatically in Figure 1, and is briefly described in the Appendix.

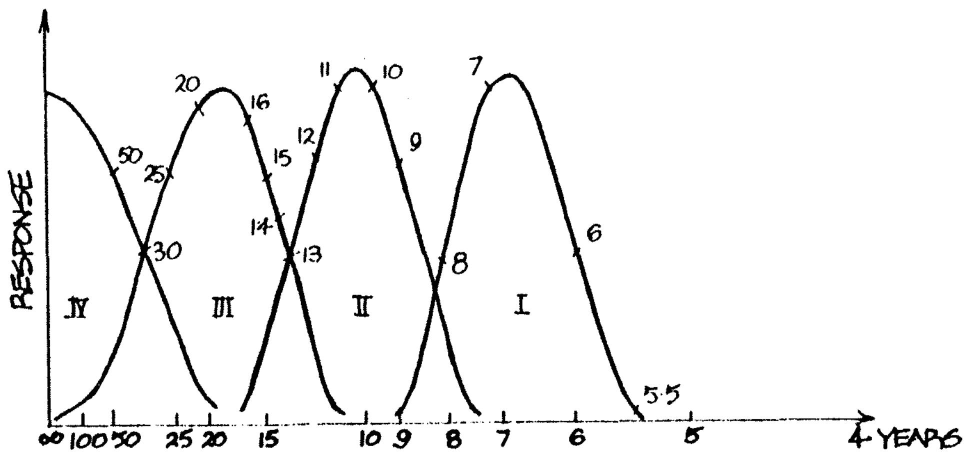


Figure 1. Diagrammatic representation of response curves for Filter system. I, II, III and IV are the four filters, each with responses over the span of years shown.

It will be seen that the filters overlap, and the response of all four filters together is nearly flat beyond about 6-1/2 years. In other words, only those fluctuations with periods shorter than 5-1/2 to 6 years are rejected by the system.

Filters I, II, and III have peak sensitivities at about 7 years, 10-1/2 years and 18 years, so that the roughly cyclic computer-outputs have approximately these frequencies*. However, broad, wide-pass filters of the present type can accommodate any variations in frequency which might be present in the rainfall

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*These periods correspond to different climatic trends reported by various workers (cf. Landsberg 1958).

records, and the output curves from the computer will adjust accordingly. Indeed, the averaging processes involved in the program include all frequencies (except, of course, those with periods shorter than 5-1/2 to 6 years)*. Thus, when the filter outputs are added together again, the resultant smoothed curve provides a good representation of the original data, and clearly illustrates the trends in rainfall over the years (cf. Fig. 2 as discussed below).

RESULTS OF THE ANALYSES

A typical example is given in Figure 2, which shows results for the analysis of rainfall at Swift Current, Saskatchewan, from 1920 to 1967. Curve IV is the shifting-mean-rainfall over this period, as derived from the computer: and Curves I to III represent periodic fluctuations in rainfall detected by the other filters. On summing Curves I to IV the smoothed rainfall for Swift Current is obtained (Curve V), and it may be seen that the original data (joined by dotted lines) are well reproduced, although the short-term variations have been removed.

It is clear that the amplitudes of the oscillations in curves I to III vary appreciably, and that their frequencies also change slightly. When the records are analysed for towns close to Swift Current (Moose Jaw and Regina) -- and even for towns at some distance (Indian Head, Saskatoon, Battleford and Medicine Hat) -- similar results are obtained. Indeed, it is surprising how close the similarities are. For when the results for all these towns are carefully compared, the individual curves from Filters I to III are always approximately in phase (although the amplitudes of the curves may be different).

This behavior is illustrated in Table 1, where details are given for all the Prairie towns, in addition to the ones mentioned above. Those years when the curves from Filter I show maxima and minima are listed, and the dates are almost the same for each centre. Further comparisons of this kind indicate that all the filter outputs (including those from Filters II and III, as well) are remarkably similar from town to town. Indeed, despite the fact that the amplitudes of the curves may vary, it is possible to derive, quite arbitrarily, a *single* set of curves of *constant* amplitude which are representative of all the towns over a very wide area. The sum of these curves is then found to

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*The filter system described will evidently respond to random numbers as well: thus, evidence of periodicity is obtained only if major features in the records are consistently reproduced in cyclic form over a considerable time-span. It follows that all longer-term regularities are difficult to assess properly when records go back only about 100 years.

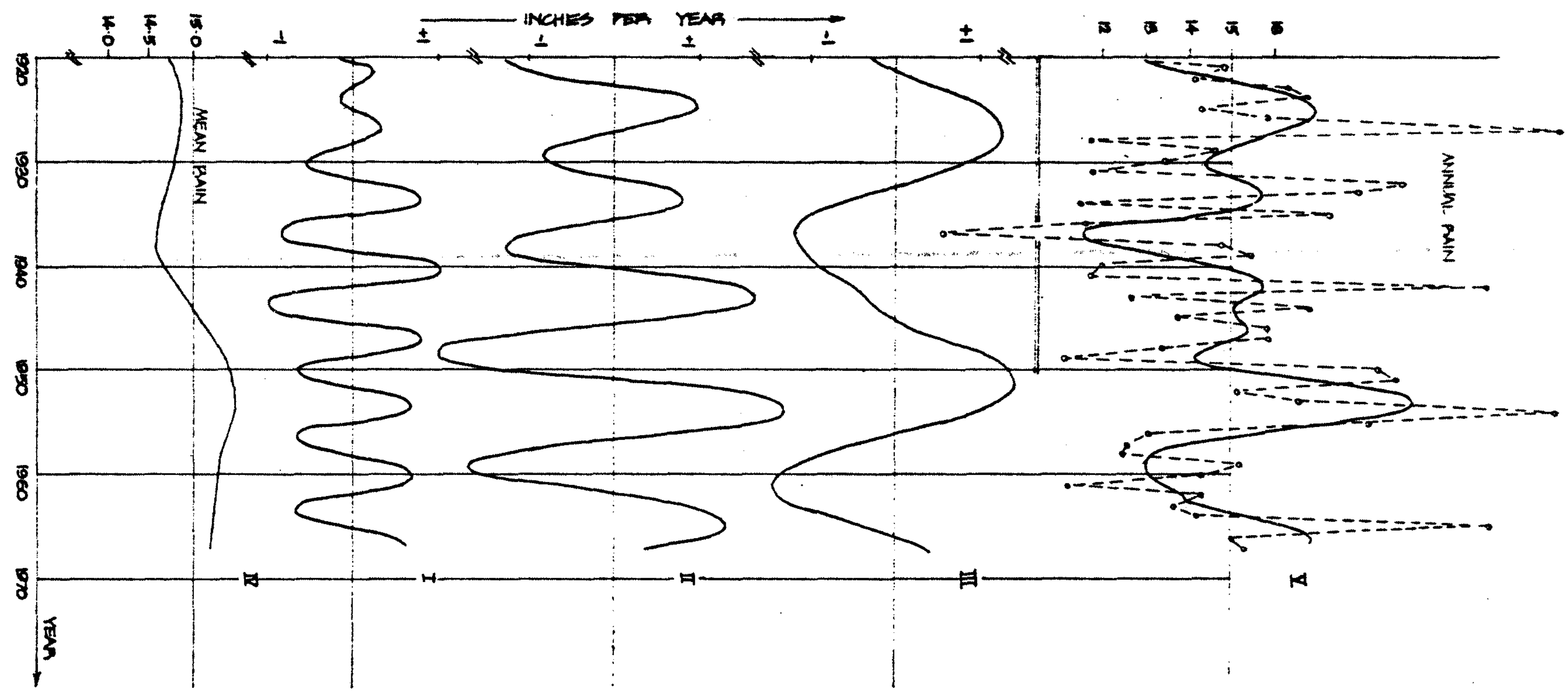

Figure 2. Analysis of rainfall-data for Swift Current (1920-1967): computer outputs (I to IV) are as indicated. The smoothed rainfall, V, is compared with the original records plotted year by year.

TABLE 1 RESULTS FOR THE PRAIRIE TOWNS: YEARS FOR WHICH CURVES FROM FILTER I SHOW MAXIMA & MINIMA

MINIMA

YEAR	1890	1900		1910		1920	1930	1940		1950	1960	
WINNIPEG	'94	'01		'09	'16	'23	'31	'38	'45	'52	'58	'65
BRANDON				0	7	4	1	8	5	2	8	5
MINNEDOSA	2	9	5	1	7	4	1	8	5			
REGINA		9	5	1	7	3	0	7	4		8	
INDIAN HEAD					7	4	0	7	4		8	
MOOSE JAW				1	7	4	0	7	4	1	8	6
SWIFT CURRENT					8	4	0	7	4	0	7	4
SASKATOON				0	7	3	1	7	4	1	8	5
BATTLEFORD			4	0	7	4	1	7				
MEDICINE HAT		8	4	0	7	3	0	7	4	0		
LETHBRIDGE			5	1	7	3	0	7				
FORT MACLEOD				1	7	4	0	6	3	0	7	
CALGARY	2	8	5	1	7	3	9	6	3	0		
EDMONTON	1	7	4	0	6	3	0	7	3	0	7	4
(NELSON)*				0	6	3	9	7	4			

MAXIMA

YEAR	1890		1900	1910		1920	1930		1940	1950		1960
WINNIPEG		'97		'05	'13	'20	'27	'34	'41	'48	'55	'62
BRANDON				6	4	1	8	4	1	8	5	2
MINNEDOSA		6	2	8	4	1	8	4	1	8		
REGINA			2	9	5	1	7	4	0	7	4	2
INDIAN HEAD					4	0	7	4	0	7	4	
MOOSE JAW					4	0	7	4	0	7	4	1
SWIFT CURRENT					5	1	7	4	0	7	4	1
SASKATOON					3	0	7	4	1	8	5	2
BATTLEFORD				7	4	0	7	4				
MEDICINE HAT		4	0	7	4	0	7	3	0	7	4	
LETHBRIDGE				8	4	0	7	4				
FORT MACLEOD				8	4	1	7	3	0	7	4	
CALGARY	9	5	2	8	4	0	7	3	9	6	3	
EDMONTON		4	0	7	3	0	7	3	0	7	4	0
(NELSON)*				6	3	0	7	3	0	7		

* NELSON, IN BRITISH COLUMBIA, IS INCLUDED FOR COMPARISON

reproduce, fairly accurately, the rainfall trends over that entire area*.

This is demonstrated in Figure 3, where results for the "Prairies" are given. Curves I to IV represent rainfall variations over the whole of the Prairie Provinces, and by summing these the resultant "Prairies" curve is obtained (Curve V). It is evident that this "Prairies" curve is not very different from the corresponding one in Figure 2 (reproduced here as a dotted line), which was derived from the rainfall data for Swift Current alone, and was representative of the town of Swift Current only. Other examples are given in Figure 4, where the smoothed rainfall curves for Montreal and Fredericton, (chosen at random from cities in the east with the necessary long-term records), are compared with the composite curve for "Quebec and the Maritimes" (see later).

When the analysis is extended to include towns from all over southern Canada, notable similarities in behavior are evident. Indeed, when all the results are compared, it becomes apparent that only four different areas need to be distinguished: "Ontario", "Quebec and the Maritimes", the "Prairies", and "British Columbia". Even then, some of the individual curves obtained in these separate areas are closely parallel, as will be described.

The overall filter curves for the four regions above are given in Figures 5, 6, and 7. Figure 5 shows those derived from the Filter I outputs: the curves for the "Prairies" and "British Columbia" are the same, as is also the case with "Ontario" and "Quebec and the Maritimes". In both the east and the west the average period is approximately 6-1/2 years; however, in the eastern provinces the curve obtained is almost completely out of phase with that for the western provinces, except for a short period of about 20 years between 1915 and 1935.

The curves from Filter II may be seen in Figures 6a and 6b. Again, the results for the "Prairies" and "British Columbia" are indistinguishable; and those for "Ontario" are not very different (Fig. 6a), except for a phase displacement of 2 to 3 years which will be referred to again later. The mean period of both curves in Figure 6a is about 10-1/2 years. However, for "Quebec and the Maritimes" the period is reduced to about 9 years (cf. Fig. 6b, where the curve for "Ontario" is again reproduced for comparative purposes). It is only over the 10 years between 1925 and 1935 that the two curves in Figure 6b are more or less coincident.

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*Because major droughts and heavy rains are widespread, their effects are usually felt over vast regions: this is probably why the long-term rainfall trends for many different towns are so similar.

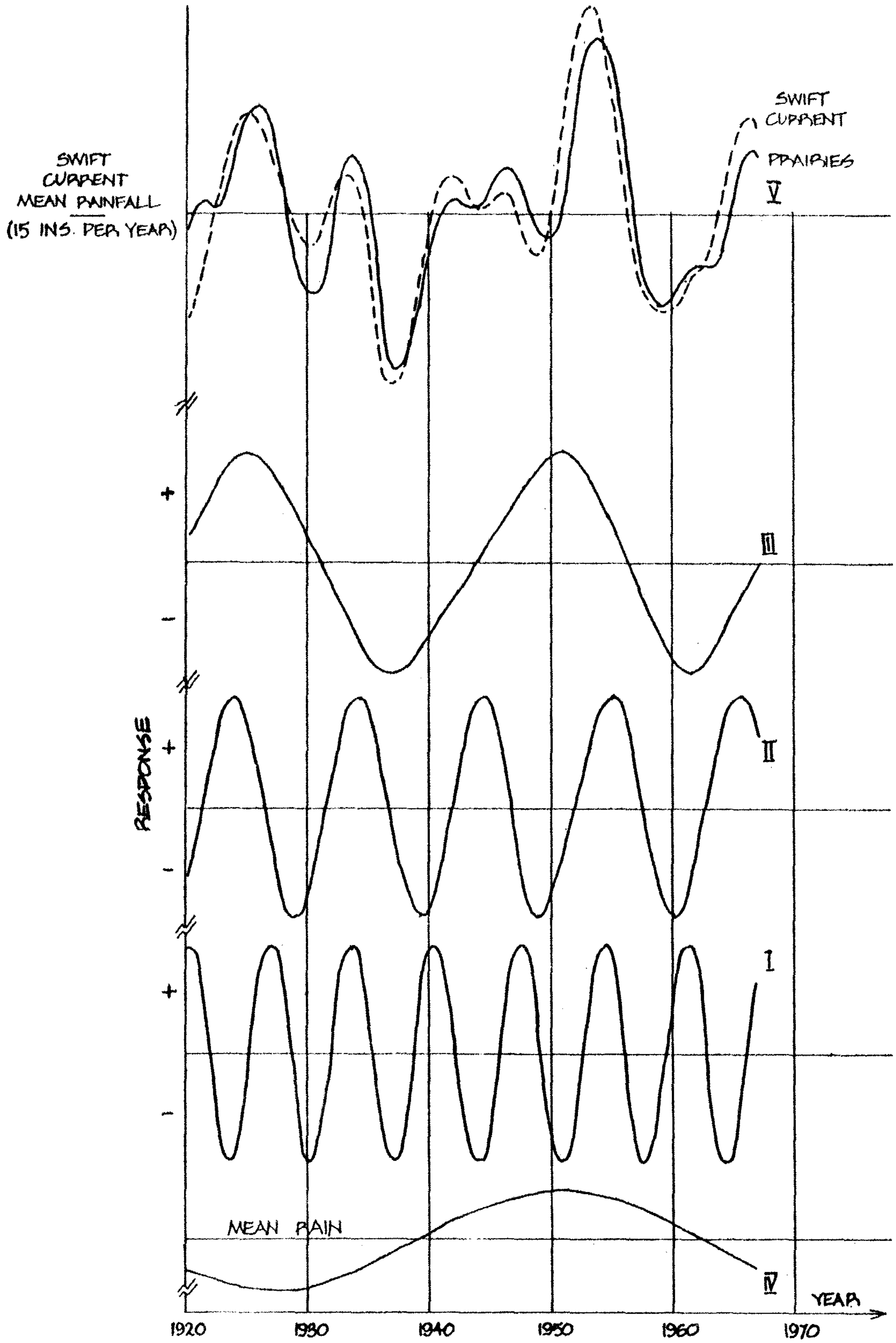

Figure 3. *Smoothed rainfall trends over the "Prairies" as a whole, from 1920-1967, and comparison with the Swift Current results as derived in Figure 2 and plotted on the same scale.*

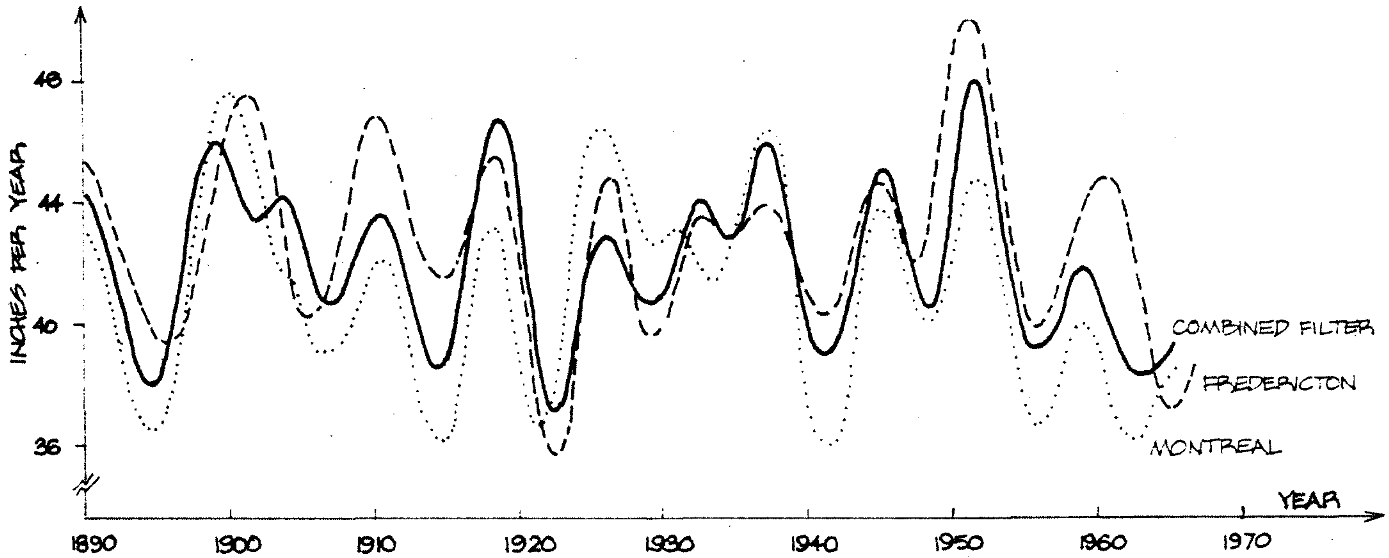

Figure 4. Rainfall trends at Montreal and Fredericton during the period 1890-1967, and comparison with smoothed rainfall for "Quebec and the Maritimes" as derived from the Filters, and drawn on the same scale.

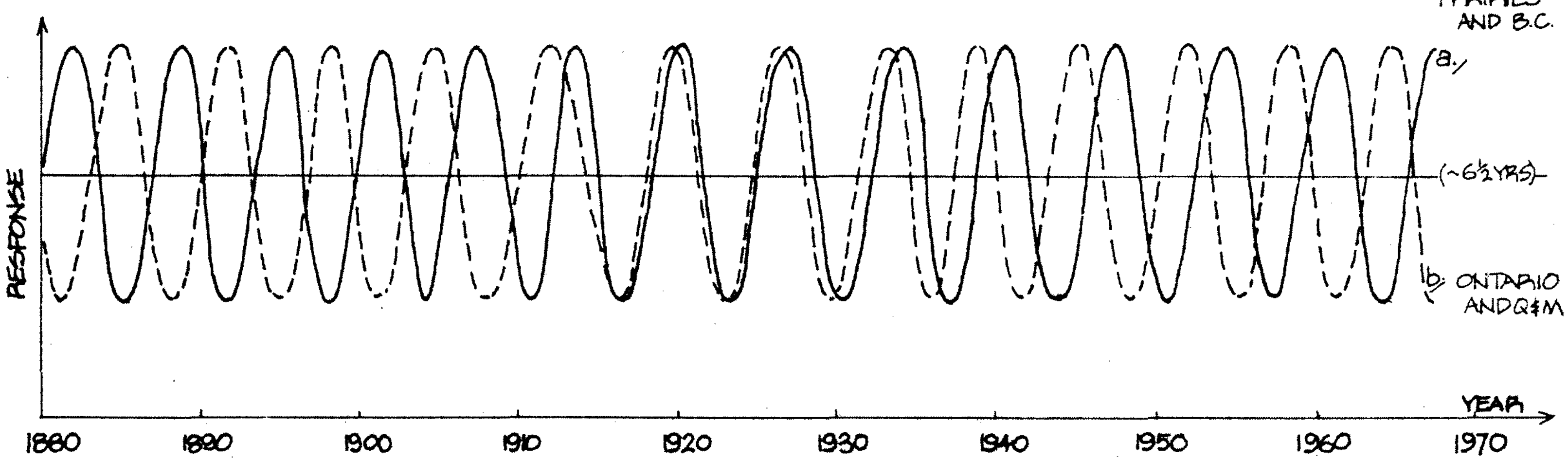

Figure 5. Representation of outputs from Filter I, for (a) the "Prairies" & "British Columbia" and (b) "Ontario" & "Quebec and the Maritimes" (scale as in Fig. 3).

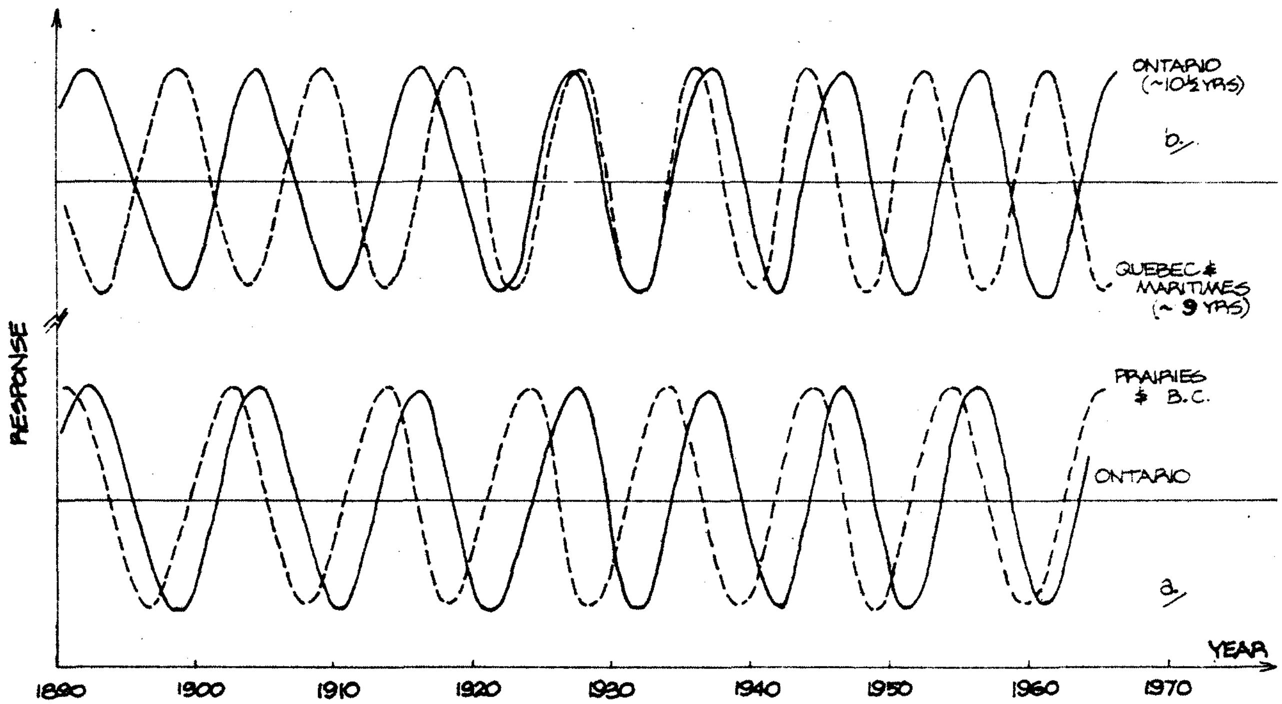

Figure 6. Representation of outputs from Filter II, for (a) "Ontario" and the "Prairies" & "British Columbia" and (b) "Ontario" and "Quebec and the Maritimes" (scale as in Fig. 3).

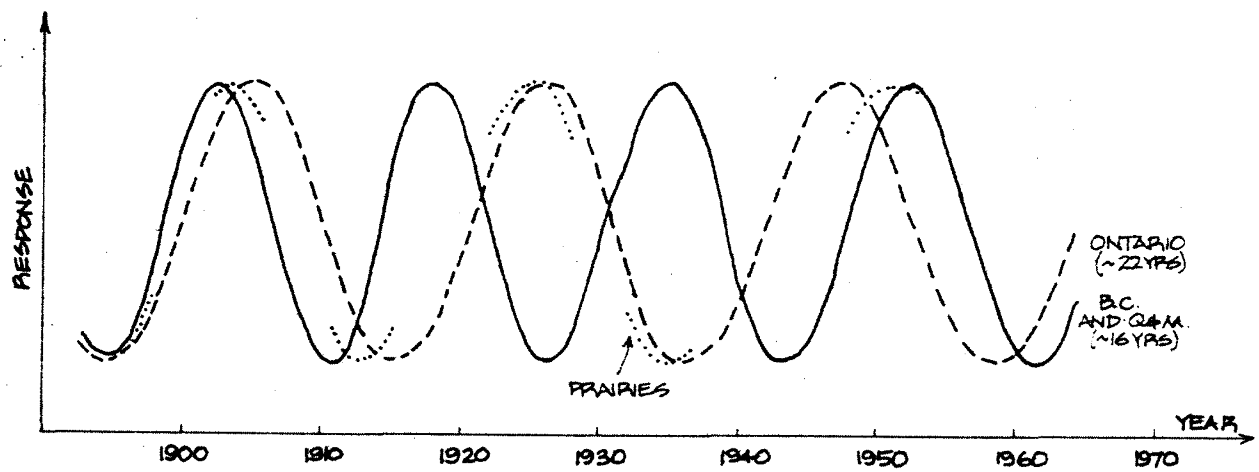

Figure 7. Representation of outputs from Filter III for "Ontario", "British Columbia" & "Quebec and the Maritimes" and the "Prairies" (scale as in Fig. 3).

TABLE 2 YEARS FOR WHICH FILTER CURVES (FIGS 5, 6, 7, 8) SHOW MINIMA

	ONTARIO				QUEBEC & THE MARITIMES				PRAIRIES				BRITISH COLUMBIA			
FILTER	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
1870																
			(1871/2)	(1871)					(1871)		(1871)					
	(1875)								('78)			(1876)				(1876)
	'81				AS FOR ONTARIO		AS FOR B.C.	(1881)	'85				AS FOR THE PRAIRIES			
	'88								'91/2		(93)					
	'94		94/5		1894	1893	1895		'98	1896/7					1895	
1900	'01	1898/9			'01											
						'03/4			'04/5							
	'08	'10/11			'08		'11		'10/11	'08	'13			1908	'11	
	'16		'15		'16	'12			'16/7				1916/7			
				20												
	'23	'21/2			'23	'21/2		'24	'23	'19			'23	'19		
							'25					'25			'25	'25
1930	29/30				'29/30				'30/1	'28/9			'30/1	'28/9		
		'32				'32										
	'35		'36/7		'35				'37/8		'36		'37/8			
	'41/2	'41			'41/2	'40/1				'40				'40		
							'44		'44				'44		'44	
	'47/8				'47/8	'49			'50	49			'50	'49		
		'52														
	'55/6				'55/6	'56/7			'57				'57			
			58/9													
1960	'61/2	'61			'61/2		'61/2			'60	'61			'60	'61/2	
						64/5			'64				'64			
	('67/8)			('69)	('67/8)			('67)	('71)	('69/70)			('71)	('69/70)		
		('71/2)														

YEARS IN BRACKETS ARE EXTRAPOLATED

For Filter III the results are as in Figure 7. Surprisingly, it is the curves for "Quebec and the Maritimes" and "British Columbia" which now coincide, the average period being about 16 or 17 years. For "Ontario", on the other hand, the behavior is different, and the average period is roughly 21 to 22 years. Results for the "Prairies" are intermediate between those for "British Columbia" and "Ontario", and the behavior is correspondingly more complex: in Figure 7 only the maxima and minima in the curve for the "Prairies" are shown since these, alone, are reasonably well defined.

The shifting-mean-rainfalls, as given by Filter IV, vary widely from town to town, and it is not really possible to make comparisons. However, in Figure 8 some attempt has been made to summarize results for "British Columbia" and the "Prairies" (which are again similar), and "Ontario" and "Quebec and the Maritimes" (both of which are significantly different).

In the preceding figures, the minima in the various curves are clearly "drought situations" as detected by the computer in the rainfall records. In order to correlate fire seasons with the incidence of drought in the four different regions, these minima have been listed in Table 2 (see page 11): comparisons can then be made with the known fire records of the different Canadian Provinces.

Comparison with Fire Data

Forest fire records from the various provinces were supplied by Mr. M.R. Lockman of the Forest Fire Research Institute, who, to avoid any possible chance of judicious selection of figures, remained unaware of the results of the rainfall studies. "Bad fire-years" have been arbitrarily defined as those in which more than .25 per cent of the protected forest area was burned. Usually losses in a "good" year are considerably less than this.

The approximate areas of forest involved are given below in Table 3.

Table 3. Details of Provincial Forest Areas.

Provinces	Area Protected (square miles)	.25% of Area Protected (acres)
British Columbia	350,000	~500,000
Alberta	150,000	250,000
Saskatchewan	~150,000	~225,000
Manitoba	125,000	200,000
Ontario	175,000	~275,000
Quebec	200,000	300,000
New Brunswick	25,000	40,000
Nova Scotia	20,000	30,000
Newfoundland	150,000	250,000

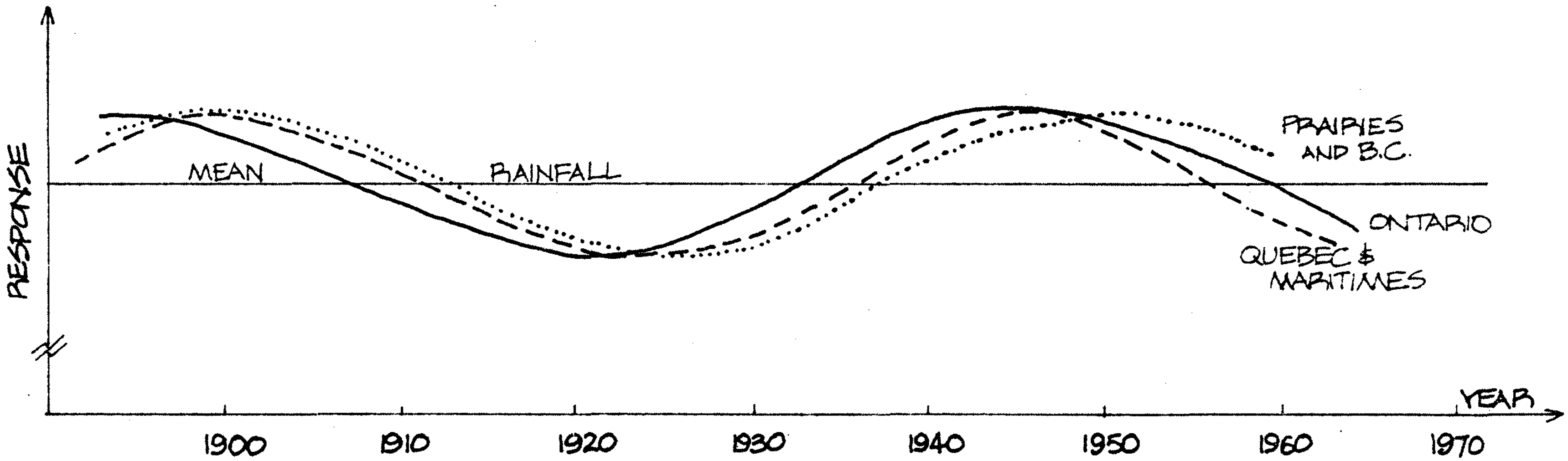

Figure 8. Approximate outputs from Filter IV: these represent the shifting-mean-rainfall in "Ontario", the "Prairies" & "British Columbia" and "Quebec and the Maritimes".

The results of the correlation between bad fire-years and the incidence of drought are shown in Table 4 (Western Canada) and Table 5 (Eastern Canada)*; these Tables give details of all areas burnt in the bad years at the various locations -- in round figures. Accurate provincial records were not available much before 1920**, but there are famous forest fires recorded in historic journals, and their dates have also been included in the Tables. The most notable of these was the great Peshtigo fire of 1871 in Wisconsin: however, there were other widespread, destructive fires in the northern United States at the same time (in North and South Dakota, Iowa, Minnesota and Michigan), and in Canada parts of both Ontario and the Prairies were also affected.

Although agreement is not always exact, it may be seen that there is remarkably good correlation between bad fire-years and those years listed in Table 2, which were derived from the computer analysis (and which are shown in Tables 4 and 5 in Columns I, II, III, and IV)***. In fact, there are only a few cases (to be discussed below) which appear as exceptions. The "historic fires", too, fit the pattern shown; and famous fires in Ontario, even earlier than those indicated in Table 5, can also be included in the correlation -- viz. the Thessalon fire in 1864 (cf. extrapolation of Column II in Table 2), and the Monteith River fire in 1855 (cf. extrapolation of Column I in Table 2).

It could be argued that, with so many years listed in the two Tables, at least some of the apparent agreements could be coincidental. Even so, the correlation is so good it is hard to avoid the conclusion that fires evidently tend to occur in the

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*An alternative procedure would be to subject the yearly fire statistics to the filter system (without any arbitrary definition of bad fire-years), and then compare the results obtained with those from the rainfall records. This has been done with the figures for Ontario. Maxima in the "fire" curves correlated well with minima in the "rainfall" curves, as given in Table 2: in other words, the extent of correlation shown in Table 5 was fully substantiated.

**1950 in Newfoundland.

***Although bad fire-seasons were observed in Quebec and the Maritimes in 1967-68, there were no large fires in Ontario. Nevertheless 1967 was a *potentially* bad year in Ontario; and the absence of bad fires was probably the result of effective suppression activities.

TABLE 4 BAD FOREST-FIRE YEARS IN WESTERN CANADA
(FIRE LOSSES IN ACRES)

YEAR	I	MANITOBA & SASKATCHEWAN	ALBERTA	BRITISH COLUMBIA	II	III	IV
1871	('71)	('71) HISTORIC PESHTIGO FIRE				('71)	
1908				('08) HISTORIC COURTENAY FIRE	'08		
1910							
12		—NO FIRE RECORDS—					
14							
16							
18		('19) 5 MILLION	('19) 1 MILLION		'19		
1920							
22	'23		(22) > 1/2 MILLION	('22) 1 1/2 MILLION			
24		('24) 1/2 MILLION	('24) > 1/2 MILLION	('25) > 1 1/4 MILLION		'25	'25
26							
28		('28) ('29) 5 MILLION		('29) 1 MILLION	'28/9		
1930	'30/1	('30) 1 MILLION	('31) > 1/2 MILLION *	('31) 1 MILLION			
32							
34							
36	'37/8	('36) ('37) 4 MILLION (FORT FRANCES 1938)†	('37) ('38) 2 1/2 MILLION	('38) 3/4 MILLION			
38							
1940		('40) 1 1/4 MILLION	('41) 1 1/4 MILLION		'40		
42							
44	'44		('44) 3/4 MILLION				
46							
48		('48) ('49) 1 1/2 MILLION	('49) 1 1/2 MILLION		'49		
1950	'50		('50) > 1/2 MILLION	('50) 1 MILLION			
52							
54							
56			('56) > 1/2 MILLION				
58	'57	('58) > 3/4 MILLION		('58) 2 MILLION			
1960		('60) ('61) 5 1/2 MILLION		('61) 1 1/4 MILLION	'60	'61	
62							
64	'64	('64) 2 MILLION					
66							
68			('68) 1 MILLION		'69/'70		
1970	('71)	('70) 1 1/4 MILLION		('71) 1 MILLION			

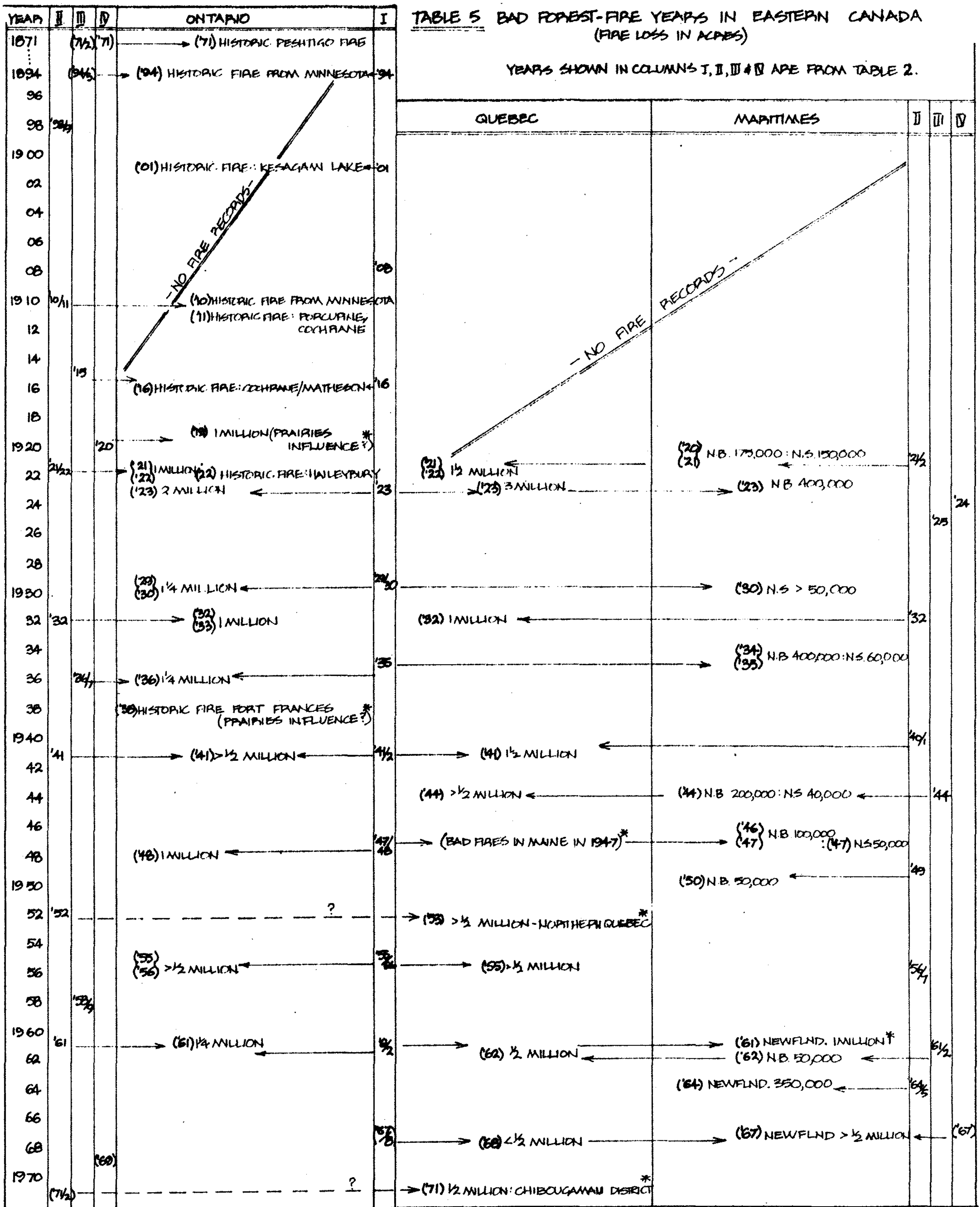
YEARS SHOWN IN COLUMNS I, II, III & IV ARE FROM TABLE 2.

* FIRE RECORDS FROM THE PRAIRIES FOREST INDUSTRIES DIVISION SHOW 2 MILLION ACRES FOR ALBERTA IN 1930/31; BUT ALTHOUGH THIS FIGURE IS DIFFERENT, IT DOES NOT AFFECT THE EVIDENT CORRELATION SHOWN.

† FORT FRANCES FIRE – cf TABLE 5

TABLE 5 BAD FOREST-FIRE YEARS IN EASTERN CANADA
(FIRE LOSS IN ACRES)

YEARS SHOWN IN COLUMNS I, II, III & IV ARE FROM TABLE 2.



* INFLUENCE FROM NEARBY AREA (SEE TEXT). † NO FIRE RECORDS FOR NEWFOUNDLAND BEFORE 1950.

various provinces at periods of about 6 to 7 years, and of about 10-1/2 years*. It will be recalled that these are exactly the same periods as those found in Australia (see Introduction).

In Table 5 reference is made to possible "influences from nearby areas", when weather in adjacent regions evidently had a profound effect on the behavior of the fires mentioned. As an example, the famous fires in Maine in 1947 were clearly affected by the same weather systems as those which, in "Quebec and the Maritimes", were associated with the bad fires in New Brunswick and Nova Scotia. Again, the historic fire in 1938 at Fort Frances, in western Ontario, may well be attributed to those weather influences which caused the extreme fire situation in the Prairies and Western Canada in 1937 and 1938. For it is obvious that the arbitrary division of Canada into the four major areas proposed in this paper does not mean exact conformation with provincial boundaries. A similar explanation is probably appropriate to the bad fires in Ontario in 1919 which were exclusively in the western and central parts of the province -- for, in the same year, 6 million acres of forest in the nearby Prairies were burnt.

There are two other references to "influences from nearby areas" in Table 5. Both concerned large fires in northern Quebec -- the first during 1953 in the region stretching from Lake St. John to a little south of Lake Abitibi on the Ontario border, and the second during 1971 in the Chibougamau area south of Lake Mistassini. In Table 5, these northern fires, have again been tentatively assigned to "Ontario" rather than to "Quebec" (cf. footnote below)**.

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*Only on a few occasions do fires occur at those longer periods shown in Columns III and IV in the two Tables: for, mostly those periods merely serve to reinforce the shorter periods which are given in Columns I and II.

**When there is a significant change in latitude in the areas studied, the curves from Filter II exhibit a phase change -- even as there is a similar phase-change with change in longitude (cf. Fig. 6a). The timing of the fires mentioned above could be explained in this way, since any such phase-change for northern Quebec would produce a weather pattern more like that found in southern Ontario (see Fig. 6b).

The effect of latitude in determining this kind of phase-change was strikingly demonstrated when the rainfall records for the towns of Churchill and Dawson were briefly examined with the computer. The curves from Filter II for these northern towns were completely out of phase with those for corresponding towns in the southern parts of Ontario and Manitoba, and British Columbia.

A further interesting point emerges from a study of Tables 4 and 5. The years in brackets at the bottom of Table 2 have been extrapolated from the other figures -- based on rainfall records up to 1967 -- and, in fact, there were fires in both Eastern and Western Canada at the times shown. This extension of the Tables beyond 1967 tends to support the authenticity of the weather patterns established in the computer analysis*.

DISCUSSION

I. Oceanic and Atmospheric Factors

When Table 2 is examined closely, various interesting features emerge. The outputs from Filters I and II for the "Prairies" and "British Columbia" are indistinguishable (see Columns I and II), as also are those from Filter I for "Ontario" and "Quebec and the Maritimes". Moreover, it is remarkable that the long-term (Filter III) pattern in Column III for both "British Columbia" and "Quebec and the Maritimes" is about 17 years (in comparison with 20 to 22 years for "Ontario"); and not only is the period the same in both these areas, but both are in phase. It is possible that "coastal" phenomena contribute to this rather odd result -- which may be due to oceanic (or atmospheric) influences arising elsewhere, conceivably in Arctic areas. On the other hand, the finding may merely reflect differences between continental and maritime climates.

It was mentioned previously, that the outputs from Filter I for Eastern and Western Canada are completely out of phase for most of the time between 1880 and 1970 (cf. Fig. 5). The change is sudden, occurring somewhere between Thunder Bay and Winnipeg -- with the former behaving like eastern, and the latter like western, towns. This abrupt reversal in behavior across mid-Canada could be connected with the profound effects which Hudson Bay and the Great Lakes have on atmospheric circulation over the continent.

II. Weather Patterns

The results in Tables 4 and 5 provide some evidence that large fires in Canada occur periodically. The implication is

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*In this connection, one additional piece of evidence should be mentioned. When rainfall records extending over 100 years, or more, are divided into two separate sets with a span of about 50 years and each set is processed individually by the computer, the results obtained are scarcely to be distinguished from those for the combined figures. This again supports the authenticity of the derived weather patterns -- particularly since there is, usually, no obvious discontinuity in the middle years where the two sets of records join.

that there are similar regularities in the weather and rainfall patterns across the continent.

If these regularities in rainfall do exist one might expect some relationship between them and other phenomena. In this connection the rainfall pattern for "Ontario" is of interest -- see Figure 9 where Curves I to IV are, as before, the smoothed outputs from the Filter analysis (cf. Figs. 5 to 8). Curve V, the sum of the other curves, represents rainfall trends in the province over the years 1880 to 1967, and periods of excessive rainfall are indicated by the peaks in this curve. It is evident that the major peaks, some 20 years apart, are approximately in phase with the sunspot maxima in 1884, 1905, 1928, 1947 and 1967. A closer inspection of Figure 9 reveals that the maxima of both Curves II and III are almost exactly in phase with individual sunspot maxima -- as indicated by the arrows in the Figure.

There is other evidence of relationships between sunspots and weather. From dendrochronological measurements (see, for example, Abbott 1936) it is known that trees in many parts of the North American continent show pronounced 20 to 22 year growth patterns -- as displayed by the growth rings. This phenomenon has generally been attributed to sunspot activity and accompanying wet seasons, during which times tree growth is stimulated.

Wright's attempt to relate the incidence of forest fires with the sunspot cycle has already been mentioned (see Introduction). Wright also drew attention to the fact that the phase relationship between fire occurrence and sunspot minima changed progressively from the East Coast to the Canadian Prairies; a phase change of this kind has also been noted here (cf. Fig. 6a). It is therefore proposed that the long-term weather variations discussed in this paper are probably to be associated with sunspot activity*.

III. General

By far the most important correlation arising from the present investigation is that between fire-occurrence in southern

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*If sunspots are important, further inferences may possibly be drawn. It is conceivable that both the 6-1/2 to 7 year periods and the 10-1/2 year periods, which emerge from the computer analysis, could be submultiples of the double sunspot cycle of 20 to 22 years. Rainfall patterns, derived by the mixing of all these periods together, might then explain the complicated 20 to 22 year tree-ring growths so often observed by dendrochronologists.

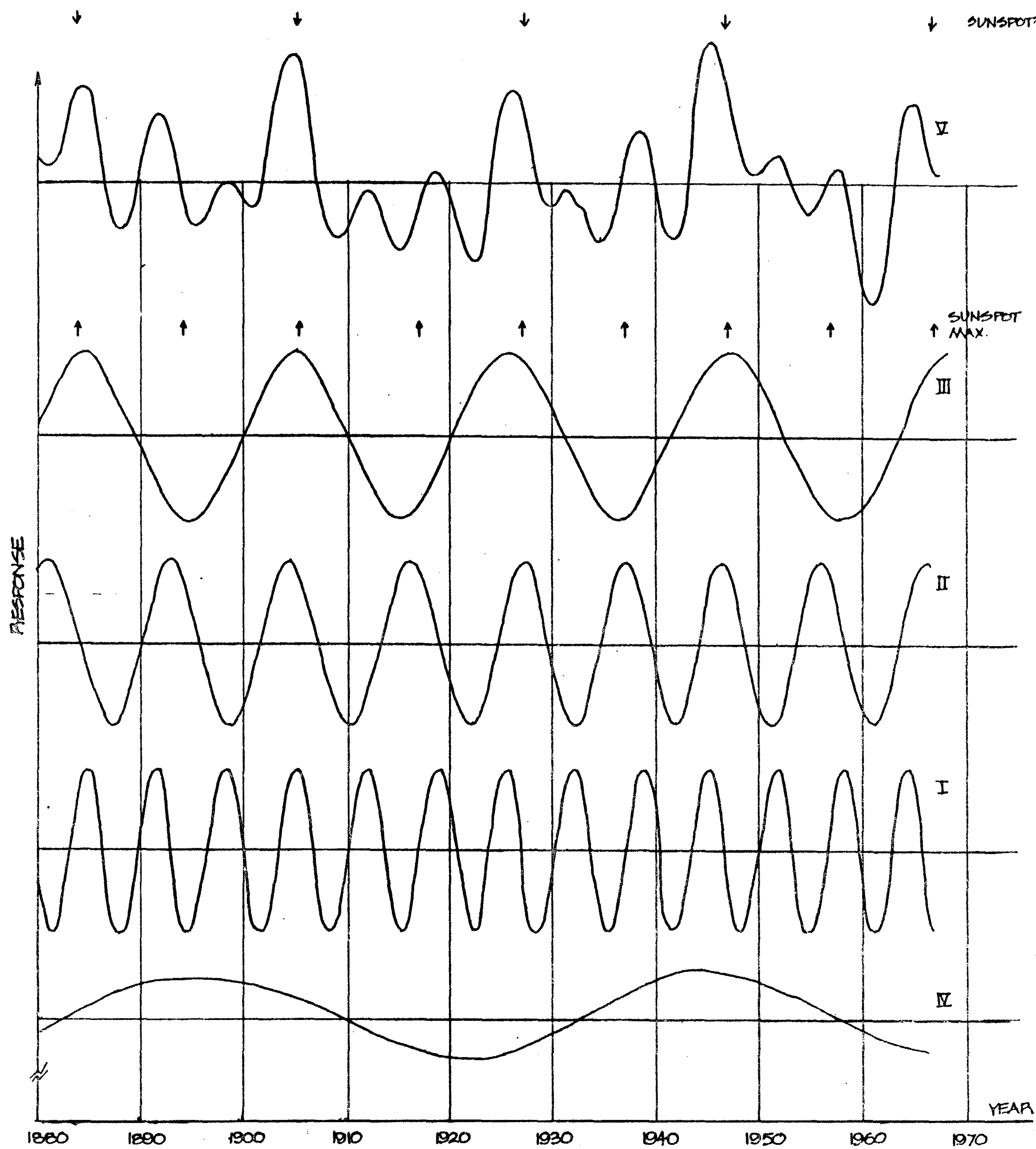

Figure 9. Rainfall pattern for "Ontario" over the period 1880-1967, with scale as in Figure 3. Years of maximum sunspot-activity are as shown.

Canada and the overall results of the computer analysis*. It is possible that the correlation incidentally includes some of the other variables contributing to the severity of fires in the hot, dry months -- e.g., wind, temperature and relative humidity -- and that these factors, too, are roughly integrated into the general "drought-situations" which emerge from the present studies of annual rainfall.

The fact that fire periodicities in Australia display marked similarities to those for Canada suggests that the associated weather phenomena may be world wide (though showing variations from place to place). This, in turn, lends support to the hypothesis that sunspot activity could be responsible for producing some of the major weather trends over the earth's surface. Any further systematic enquiry into the complex relationships between sunspots and weather would be complicated, because so many difficult statistical problems are involved. Nevertheless, the present paper raises the distinct possibility that such relationships exist.

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*It is important to stress again that this correlation was made from completely independent sources. The authors, who analysed the rainfall records, were totally unaware of possible periodicities in the occurrence of Canadian fires: and Mr. Lockman, who supplied the fire statistics, did not know the results of the computer analysis.

REFERENCES

Abbott, C.G. 1936. Cycles in tree rings. Smithsonian Misc. Coll., Vol. 19.

Boultbee, R. 1961. Forest fire periodicity. Ontario Ministry of Natural Resources.

Landsberg, H. 1958. Physical climatology. Grey, Pennsylvania.

Vines, R.G. 1969. A survey of forest fire danger in Victoria: 1937-1969. Australian Forest Research, Vol. 4(2), p. 39.

Wright, J.G. 1940. Sunspots and forest fires in New Brunswick. Forestry Chronicle, Vol. 16, p. 233.

APPENDIX

The Filtering Technique

The problem is essentially one of time-series analysis, based on Fourier techniques. The present method involves breaking up the original function provided by the data into a series of simple trigonometric functions: the filtering routine then suppresses some of these functions, and emphasizes others which are within a specific range or bandwidth.

The computer program consists of four separate filters -- a low-pass filter (moving average), and three band-pass filters with nominal periods of nineteen, eleven and seven years. When applied to the data, these filters pick up any "cycles" occurring within the ranges shown (cf. again Fig. 1).

The properties of each filter are read from punched cards at the beginning of the program. Because the response functions are in the frequency domain an inverse Fourier transform is applied to them, resulting in "filters" (or weights) which are used in the subsequent filtering routine. When these weights are applied to the data, all long-term cyclic components appear in the filter outputs, and any residuals which remain after these long-term periods have been extracted from the data consist only of short-term cycles, or random oscillations.