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As a publication of the Canadian Meteorological and Oceanographic Society, the CLIMATOLOGICAL BULLETIN provides a medium of information on climatology. The Editorial Board gives special encouragement to the submission of manuscripts on applied climatology (e.g., agriculture, commerce, energy, environment, fisheries, forestry, health, recreation, transportation, and water resources), climatic change and variability, climate impact studies, climate model applications (including physical climatology), and regional studies (including ocean areas). It is published with the aid of a grant from the Government of Canada through the Natural Sciences and Engineering Research Council.

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Contributors should submit manuscripts to Stewart J. Cohen, Editor, CLIMATOLOGICAL BULLETIN, Canadian Climate Centre, 4905 Dufferin St., Downsview, Ontario, M3H 5T4. All manuscripts should be typed double spaced on one side of good quality white paper, 28 cm x 21.5 cm, or its nearest equivalent. The abstract, list of references, tables, and a list of figure captions should be typed doubled spaced on separate sheets. Comments (including book reviews and opinions) and news items should not exceed 1 500 words. Furnish an original and three copies if possible, in the order listed below.

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The TEXT of longer contributions should be typed double spaced on numbered pages, and divided into sections, each with a separate heading and numbered consecutively. The section heading should be typed on a separate line.
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FIGURE LEGENDS must be provided for each figure, and should be typed together, double spaced, on a separate sheet.
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Authors should use the International System of units, but may show other units in parentheses. Authors should provide instructions in the margin for any special type required (Greek letters, capitals, bold face, etc.).

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Publication de la Société canadienne de météorologie et d'océanographie, le Bulletin climatologique offre un moyen d'information sur la climatologie. Le comité de rédaction encourage en particulier la soumission de manuscrits sur la climatologie appliquée (comme l'agriculture, le commerce, l'énergie, l'environnement, la pêcherie, la sylviculture, la santé, les loisirs, les transports, et les ressources en eau), les changements et la variabilité du climat, la prospective climatologique, les applications des modèles du climat (inclus la climatologie physique), et les études régional (inclus les océans). Il est publié grâce à une subvention accordée par le gouvernement canadien par l'intermédiare du Conseil de recherches en sciences naturelles et en génie.

Les auteurs peuvent choisir de soumettre leurs manuscrits aux "Articles", "Notes de Recherches", ou "Nouvelles et Commentaires". Ils doivent l'indiquer sur la lettre d'accompagnement du manuscrit. Les articles de recherche et les "Notes" sont indépendamment soumis à l'examen d'au moins deux appréciateurs anonymes. Le rédacteur en chef examine les "Nouvelles et Commentaires" conjointement avec le comité de rédaction. On accepte les articles soit en français, soit en anglais. Il faut envoyer un résumé, de préférence en français et en anglais.

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LA PAGE DE TITRE doit comprendre: nom, prénoms des auteurs, ainsi que les affiliations professionnelles.

LE RÉSUMÉ, dactylographié sur une page à part, ne doit pas compter plus de 250 mots.

LE TEXTE. Il faut taper à double interligne, sur des pages numérotées, le texte des articles plus longs et le diviser en sections, chacune dotée d'une en-tête à part et numérotée dans l'ordre. Il faut dactylographier l'en-tête de section sur une ligne à part.

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Foreword / Avant-Propos

This issue includes a note on the 1984 severe local storm season by M.J. Newark *et al.* The referees felt that this type of review should be published on an annual basis as a feature item in News and Comments. Hopefully, the Bulletin will be able to offer these reviews regularly, weather permitting.

In the October 1986 issue, I noted the decision by CMOS Council to institute voluntary page charges for research articles and notes. The NSERC grant still has 2 more years to run, but there are no guarantees of support beyond 1989. The page charges should eliminate most of our operating deficit for now, and as the Bulletin continues to grow, additional subscriptions will ensure financial viability over the long term.

As we look to the future, it gives me great pleasure to announce the appointment of Terry Allsopp and Bonnie Magill to the Board as Associate Editors. Their nominations were approved at CMOS Council Meeting No. 2, held September 8, 1986.

Stewart J. Cohen

The Spatial Distribution of Heavy Precipitation in the Greater Victoria Region

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[Original manuscript received 7 March 1986; in revised form 27 May 1986]

ABSTRACT

The distribution of precipitation during heavy rainfall events is an important and practical aspect of the precipitation climatology of an area. The mapping of the spatial distribution of total storm precipitation revealed two basic distribution patterns of heavy precipitation in the Greater Victoria region. The first pattern, characteristic of storms of moderate intensity, resembled that of annual total precipitation. The second, not before described in discussions of the precipitation patterns in the Greater Victoria region and associated with some of the most intense storms, had high precipitation totals in the usually drier southeastern part of the region, and low totals in the relatively wet north. A preliminary analysis indicated that direction of upper air wind flow was best able to distinguish between the two distribution patterns. The first pattern occurred during flow from the southwest quadrant, whereas the less frequent, second pattern was associated with winds from the northwest quadrant.

RÉSUMÉ

La pluviométrie est un aspect important de la climatologie météorologique d'une région. Le relevé cartographique des précipitations totales d'orage révèlent deux modèles pluviométriques fondamentaux dans le grand Victoria métropolitain. Le premier modèle qui est caractéristique des orages de moyenne intensité, ressemble à la précipitation annuelle totale. Le second modèle, jamais décrit auparavant pour discuter le mode de précipitations affectant le grand Victoria métropolitain et lié à quelques-unes des plus violentes orages, indique des taux de précipitations élevés dans la région sud-est habituellement sèche, et peu élevés au nord dans la région humide. L'analyse préliminaire révèle que la direction des masses d'air à haute altitude est le mieux à même de distinguer entre les deux modèles. Le premier modèle survient durant des courants atmosphériques venant du sud-ouest, quant au second modèle, moins fréquent, est associé aux vents du nord-ouest.

Climatological Bulletin / Bulletin climatologique 21(1) 1987

1. INTRODUCTION

A knowledge of the spatial distribution of precipitation during heavy rainfall events is important in many aspects of applied climatology and hydrology. The design of stormwater drainage systems, assessment of erosion potential and the evaluation of flood risk and flood control strategies are just a few common, practical examples. The distribution of mean annual precipitation over most populated areas is reasonably well known. The distribution of heavy precipitation from individual severe storms can be quite variable, however. This is especially true of convective storms. Even the long term, climatic pattern of heavy precipitation can differ from that of mean annual precipitation. Thus, it is often necessary to make an independent assessment of its distribution and not rely on the better known distribution of total precipitation.

The purpose of the present study is to present the pattern of precipitation during heavy rainfall events in the Greater Victoria, British Columbia, region; and to see how this pattern relates to that of mean annual precipitation. Most precipitation in Victoria is produced by mid-latitude cyclonic storms. This combined with the dominant influence of orographic controls should produce a more consistent distribution of storm precipitation than that found in areas of low relief where small size, convective storms are responsible for most of the heavy rainfall events. The relief features, both local relief and nearby hills and mountain ranges, also produce a marked variation in precipitation across the region. This makes the Greater Victoria area an interesting laboratory in which to investigate the spatial variations in storm precipitation. Although the emphasis in the present study is on the spatial variation, some possible reasons for different distribution patterns are suggested.

2. METHODOLOGY

The term "heavy" precipitation event, as used in this study, refers to a storm in which 40 or more mm of total precipitation was recorded during one climatological day at either of the two principal climatological stations in the Greater Victoria region: Victoria Gonzales Heights or Victoria International Airport. The term "rainfall" is used synonomously with "precipitation" because most of the heavy precipitation in Victoria falls as rain. These storms are subdivided into two categories. Storms of "moderate intensity" are defined as those that produce between 40 and 60 mm of total precipitation per day. "Intense" storms produce over 60 mm.

The Greater Victoria region considered here is similar to that included by the Atmospheric Environment Service in its *Monthly Meteorological Summary* for the area. It includes metropolitan Victoria (the municipalities of Victoria, Oak Bay, Esquimalt and Saanich); and the rural-

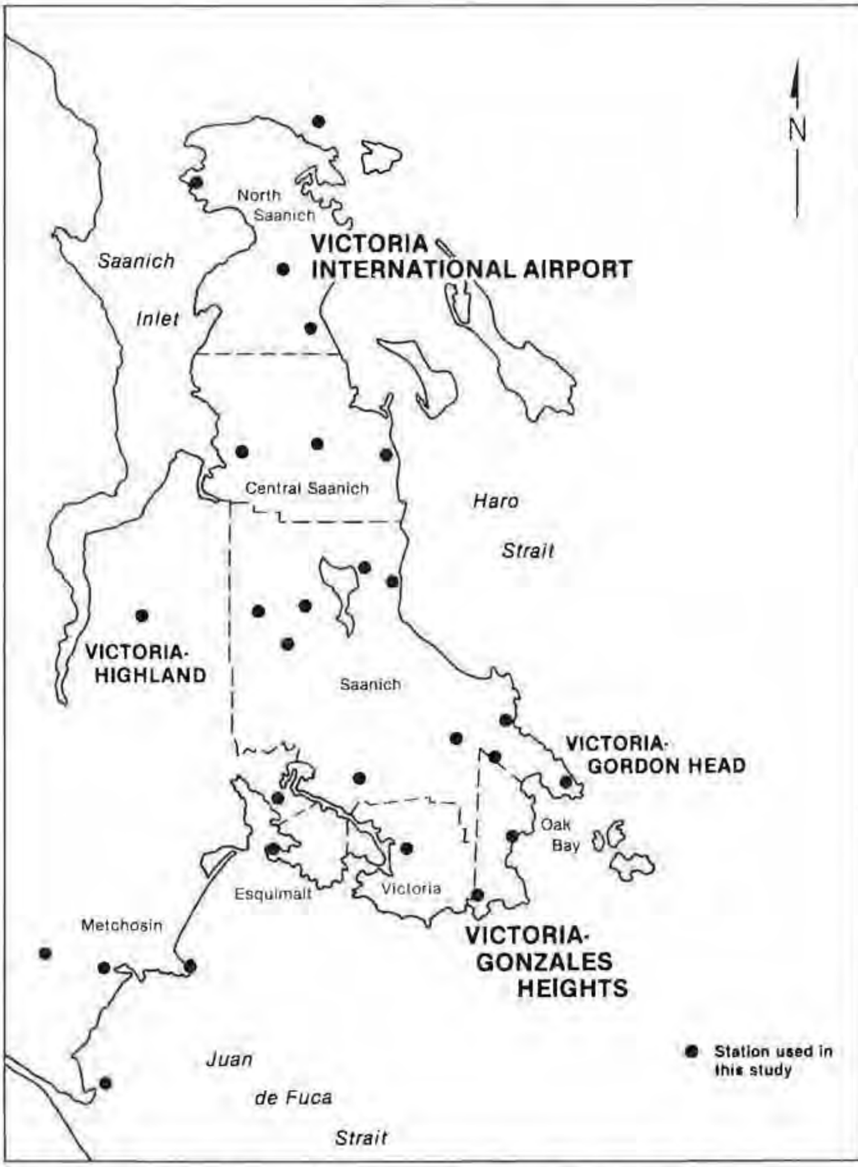

FIGURE 1. Map of the Greater Victoria region and stations used in this study.

suburban areas extending northward through the Saanich Peninsula and westward to the foothills of the hills and mountains of central Vancouver Island (Figure 1). A total of 27 stations which had data for sufficient storms are included in the analysis.

Heavy precipitation events which occurred during the 1968 to 1984 period were selected on the basis of high one-day totals at Victoria Gonzales Heights and Victoria International Airport. Maps of the distribution patterns were prepared based on 18 events or storms. Two additional storms were included for the examination of possible controls of the different distribution patterns.

One-day precipitation totals were used in this study because this is the minimum time unit available at most of the stations in the area. Although the intensity over shorter time intervals might be of more interest for design purposes and other applications, recording rain gauge data were available for only two to four stations depending on the storm. This number was not adequate for the present study which is interested in the distribution of precipitation throughout the region.

The one-day rainfall totals are measured using standard procedures and the standard rain gauge at all stations. During the time period covered by this study the older, copper, Type A gauge was being replaced by the larger, plastic, Type B gauge. Although there is no uniformity in type of gauge employed at all stations during the more recent storms the type of gauge should not be a factor in different recorded rainfall amounts.

Victoria Gonzales Heights and Victoria International Airport each have a Nipher snow gauge. None of the storms analysed in this study produced only snow with no rain. Total precipitation in storms with a mixture of snow and rain is measured with the rain gauge at all stations when snowfall is light enough that it does not plug or overflow the gauge. The amount of water produced by rain and melted snow in the snow gauge is recorded as the total precipitation at the two principal climatological stations in storms when the rain gauge does not adequately handle the snow. Thus, some difference in results could occur in storms with heavy snowfall. Snow was reported in four of the 18 storms analysed here but in only one did it represent an important addition to total precipitation.

The total precipitation recorded during the storm event rather than that for the day of heaviest precipitation was used to overcome the problem of different observation times. Prior to January 1, 1982, the climatological day ran from 10:00 p.m. to 10:00 p.m. Pacific Standard Time at both Victoria International Airport and Victoria Gonzales Heights, and from 8:00 a.m. to 8:00 a.m. at most other stations in the area. Gonzales Heights has been using a 10:00 a.m. to 10:00 a.m. period since January 1, 1982. Thus, the same amount of precipitation falling at the same times could show up as different daily totals because of the 10 to 12 hour deviation in observation time among stations. Although the precipitation events were selected on the basis of high one-day totals the actual analysis included the bulk of the precipitation credited to adjacent days as well.

Recording rain gauge data were used to verify that the ranking of available stations in terms of total storm precipitation was similar to the ranking in terms of shorter duration precipitation.

The ratio of storm precipitation at a particular station to that at Victoria Gonzales Heights is used to illustrate the variation of storm precipitation. The relative rather that the absolute variations are highlighted. Gonzales Heights was selected as the reference station because it has the longest continuous record of any station within the study area and is the station whose data have most often been quoted in studies describing the climate of "Victoria."

An initial inspection of the data revealed that two distinct patterns of storm precipitation existed in the Greater Victoria region. One, composed primarily of storms of moderate intensity, showed higher amounts at Victoria International Airport and the northern part of the study area than at Victoria Gonzales Heights and the Oak Bay area. Gonzales Heights and the southeast had higher totals during many especially heavy precipitation events, however. Each of these two cases had its own unique precipitation distribution pattern. Each case was mapped separately in order to present a comprehensive picture of the distribution of heavy precipitation. Nine storms were included in each group. A composite map was also constructed to portray the overall pattern of heavy precipitation in the Greater Victoria area. Ten of the original 18 storms were selected for this map based on the data recorded at two stations with complete records located near the centre of the region (Victoria Highland and Victoria Gordon Head). The one-day precipitation totals at these stations were added together and the ten storms with the largest totals were selected. These are the storms that brought the most precipitation to the centre of the Greater Victoria region irrespective of the relative difference between the north and southeastern sections.

The median ratio of storm precipitation at a particular station to that at Gonzales Heights is reported. The use of the median rather than the mean reduces the effect of extreme values and in most cases produces a conservative estimate of the deviation of precipitation from that at Gonzales Heights. The median ratios are given as dot symbols for each station. This eliminates the errors inherent in drawing isolines through an area where a great deal of local variation can exist and avoids giving an impression of accuracy that is unwarranted by the available station density. In the rare cases where the median ratio was on the boundary between two classes, the mean and the distribution of values were used to determine whether the station belonged in the higher or lower category.

Although the precise pattern of precipitation in the Greater Victoria region will vary from storm to storm and the mapped patterns will depend on the particular cases included, the maps presented in this study should be indicative of the expected regional pattern of heavy precipitation.

Selected surface and upper air data and characteristics of each storm were stored in a microcomputer. A database management system was used to select those factors that either singly or in combination correctly differentiated the storms in which Victoria Gonzales Heights had the higher precipitation total from those in which Victoria International Airport received more. Although this does not prove cause and effect, it does indicate the conditions which were closely associated with one distribution pattern versus the other.

Surface wind direction, wind speed, form of precipitation and relative humidity at both Gonzales Heights and the Airport were taken from the *Monthly Meteorological Summary for the Greater Victoria Region.* Approximate surface vapour pressure was determined from the relative humidity and air temperature. The storm track and front type were obtained from the 1200 GMT (0400 PST) surface analysis weather maps drawn by Pacific Weather Centre in Vancouver and the 1200 GMT maps published in NOAA's *Daily Weather Maps.* This latter source also provided the 1200 GMT 500 mb wind direction.

The distribution of 1951-1980 normal, annual total precipitation was mapped using the data published by the Atmospheric Environment Service (1982). The isohyets, at an interval of 100 mm, were interpolated with the aid of the patterns presented by Chilton (1973) and Coligado (1980).

3. RESULTS

Distribution of Mean Annual Precipitation

The mean annual total precipitation increases from east to west across the Greater Victoria region (Figure 2). The western portion of the region is closer to the axis of the hills of central Vancouver Island and receives more orographic spillover of precipitation. The subsidence of air and the "rain-shadow" effect of the mountains become better established in the eastern parts of the region. The northern portion of the region is closer to the mountains than is the southern part at the same longitude and also is less protected by the effects of the Olympic Mountains located approximately 50 km to the southwest. The protection of the Olympics for the southern part of the region is maximized with a southwesterly air flow pattern. This is the direction of warm, moist, middle level air flow that accompanies much of the winter precipitation (Walker, 1961). The principal track of winter low pressure systems also approaches southern Vancouver Island from the southwest (Klein, 1957). Thus, there is a tendency toward more precipitation in the north although this is often overwhelmed by the east-west gradient and the effects of local relief (Figure 2).

Local relief exerts an effect that is superimposed on the east-west gradient. Higher areas like that surrounding the Victoria Highland station experience greater precipitation than do other areas. There are probably minor local differences created by smaller relief features but the station density is not adequate to fully document their extent or magnitude.

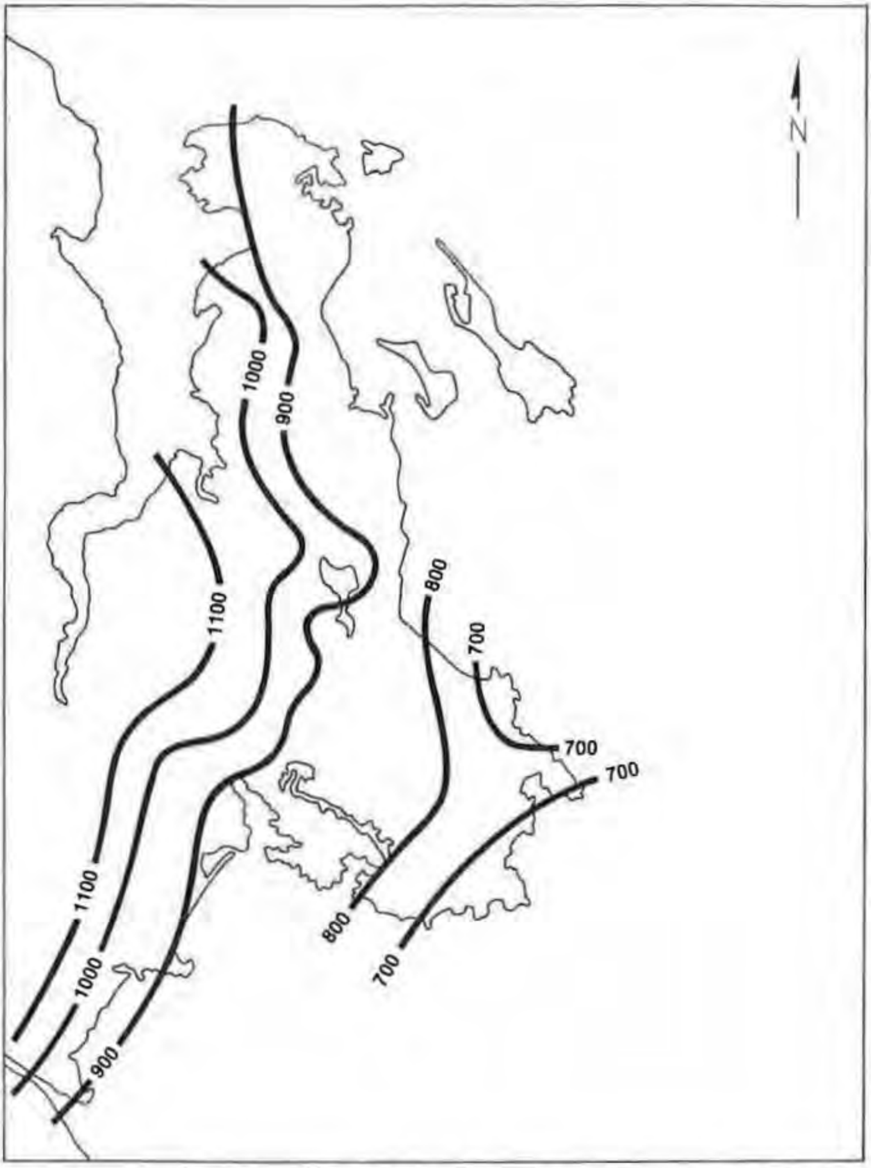

FIGURE 2. Generalized distribution of 1951-1980 normal mean annual total precipitation (mm).

Distribution of Heavy Precipitation

Heavy precipitation in the Victoria area is brought about by winter, mid-latitude cyclonic storms. December is the month with the greatest frequency of heavy precipitation events. This pattern differs from that in much of the rest of southern Canada. Convective precipitation that often brings brief but intense downpours to many other parts of the country during the summer is not often a factor in Victoria. Victoria can receive moderate convective precipitation in unstable air following fronts in the spring. The one-day totals are usually much less than those brought by severe, mid-winter cyclonic storms; however. The expected magnitude of very short duration rainfall is relatively low in Victoria (National Research Council of Canada, 1975). One-day precipitation totals are comparable but often the season and responsible storm systems differ. Stations in eastern Canada often receive their highest one-day totals from tropical cyclones which affect the area in summer or early fall rather than mid-winter. High one-day totals on the Prairies also occur in summer when frontal systems can trigger uplift in moist, unstable air. The Victoria area in the rain shadow of Vancouver Island and the Olympic Mountains, receives much less heavy precipitation than do more exposed stations on the west coast of British Columbia. Overall, the Greater Victoria area has a comparatively benign heavy precipitation regime.

The distribution of heavy precipitation does not usually mirror the distribution of mean annual precipitation. Even in an area such as Victoria where because of orographic effects we might expect a closer coincidence, the two patterns quite often do not agree. The distribution during nine events that include some of the highest one-day precipitation totals recorded in the Victoria area showed more precipitation at Gonzales Heights and the southeast of the region than was recorded in the northern Saanich Peninsula in the vicinity of the Airport (Figure 3.) One-day precipitation totals recorded at Gonzales Heights ranged from 40.1 mm to 83.3 mm in this sample. The median was 61.0 mm.

The general east to west increase in precipitation still prevailed in the distribution pattern of these storms (Figure 3). Downtown Victoria received about 20 percent more precipitation than did Gonzales Heights. The higher elevation Victoria Highland station and the Metchosin area, located closer to the mountains in the southwest, received over 35 percent more.

The distinctive feature of this heavy storm precipitation pattern was the low values in the central and northern Saanich Peninsula, a region that usually receives relatively high precipitation. The locus of lowest precipitation in the Greater Victoria region has shifted from the southeast (Oak Bay) to the north (North Saanich). The median ratio of precipitation at Victoria International Airport to that at Victoria Gonzales Heights was only 0.79.

One basic difference in the precipitation patterns seems to be in the intensity of precipitation. Victoria International Airport gets more total precipitation and much more moderate intensity rainfall. It receives 35 percent more mean annual total precipitation (873 mm compared with 647 mm at Gonzales Heights; Atmospheric Environment Service, 1982). The average highest one-day and 24-hour precipitation totals in the year are also higher at the Airport (45.1 mm and 51.9 mm respectively) than at Gonzales Heights

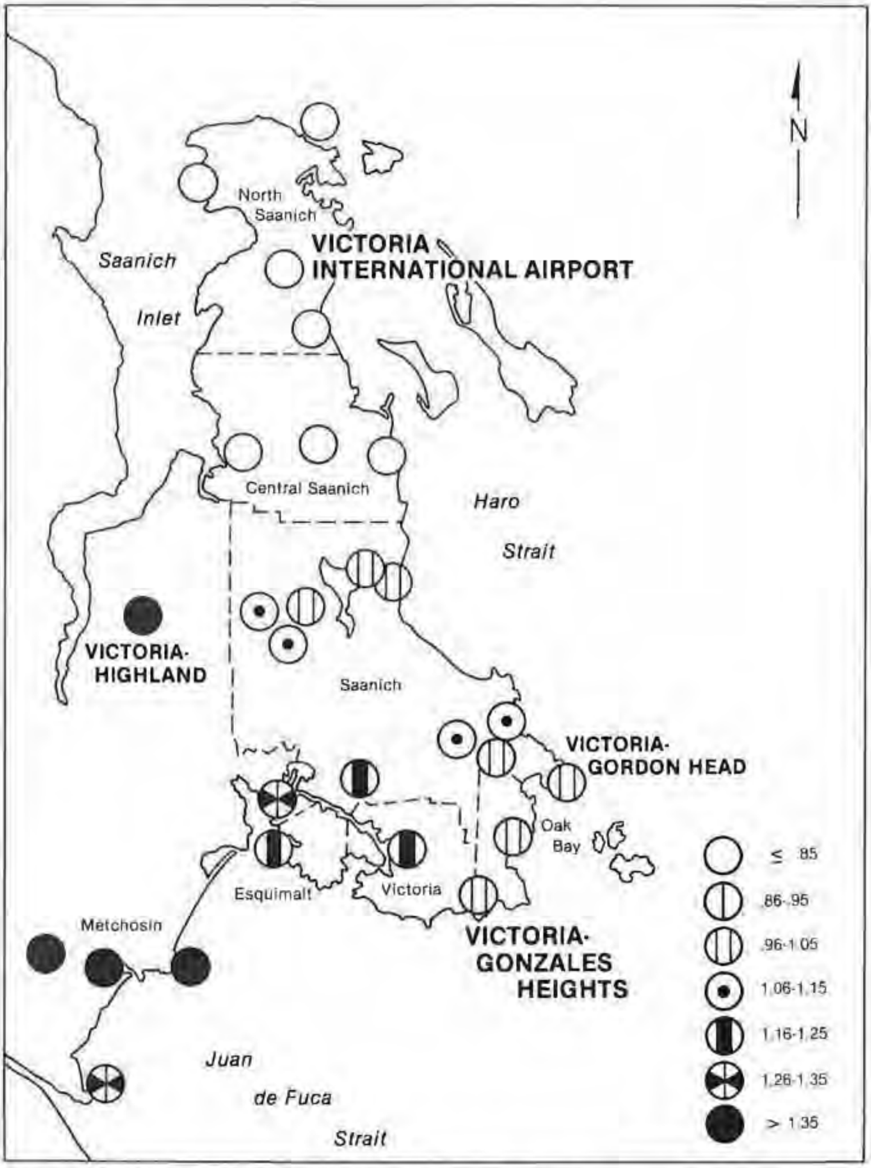

FIGURE 3. Median ratio of station to Victoria Gonzales Heights precipitation for storms when Gonzales Heights recorded more precipitation than Victoria International Airport.

(42.8 mm and 49.1 mm) over the periods of comparable record (1941-1984 for one-day precipitation and 1965-1983 for 24-hour precipitation). Gonzales Heights has more high and low values, however (Tables 1 and 2).

Many moderate intensity precipitation events have higher

TABLE 1: Five highest and five lowest one-day precipitation totals (mm) at Victoria International Airport and Victoria Gonzales Heights, 1941-1984.

Five Highest (mm)		Five Lowest (mm)	
Gonzales Heights	Airport	Gonzales Heights	Airport
83.3	72.9	17.8	24.1
81.0	68.3	20.3	28.7
80.8	64.3	21.1	29.0
72.1	62.7	24.5	29.2
68.8	59.0	24.9	31.2

TABLE 2: Four highest and four lowest 24 hour precipitation totals (mm) at Victoria International Airport and Victoria Gonzales Heights, 1965-1983.

Four Highest (mm)		Four Lowest (mm)	
Gonzales Heights	Airport	Gonzales Heights	Airport
100.2	89.2	24.1	29.2
78.4	74.2	25.6	35.4
72.1	73.3	26.9	35.8
70.1	69.5	29.7	36.3

precipitation at Victoria International Airport that at Gonzales Heights. The maximum one-day precipitation values at the Airport ranged from 41.7 mm to 72.9 mm and had a median of 53.9 mm for the nine storms examined here. The distribution of precipitation in this case (Figure 4) resembles that of the annual precipitation (Figure 2). The intensity of precipitation was least in the southeast (Oak Bay) and increased both toward the west and north. Downtown Victoria received about 15 percent more precipitation than Gonzales Heights; and the northern Saanich Peninsula and the southwest, 45 percent more. The highest values were clustered in the central part of the region and particularly, at the higher elevations. The percentage deviations were fairly large, because the Gonzales Heights precipitation was relatively low during most of these events, amplifying the percentage or ratio deviation. Still, the median difference in one-day precipitation totals between the Airport and Gonzales Heights was 14 mm.

Although the regional pattern of precipitation resembled that of annual total precipitation, the magnitude of the deviations from Victoria Gonzales Heights was somewhat different. The deviations were greater than those for mean annual total precipitation in the northern and central parts of the Greater Victoria region. They were lower in the west and similar through the metropolitan core. The relative regional variations were amplified in the storm precipitation distribution.

The composite map portrays the overall pattern of heavy precipitation in the Greater Victoria area. Six of the ten storms used for this

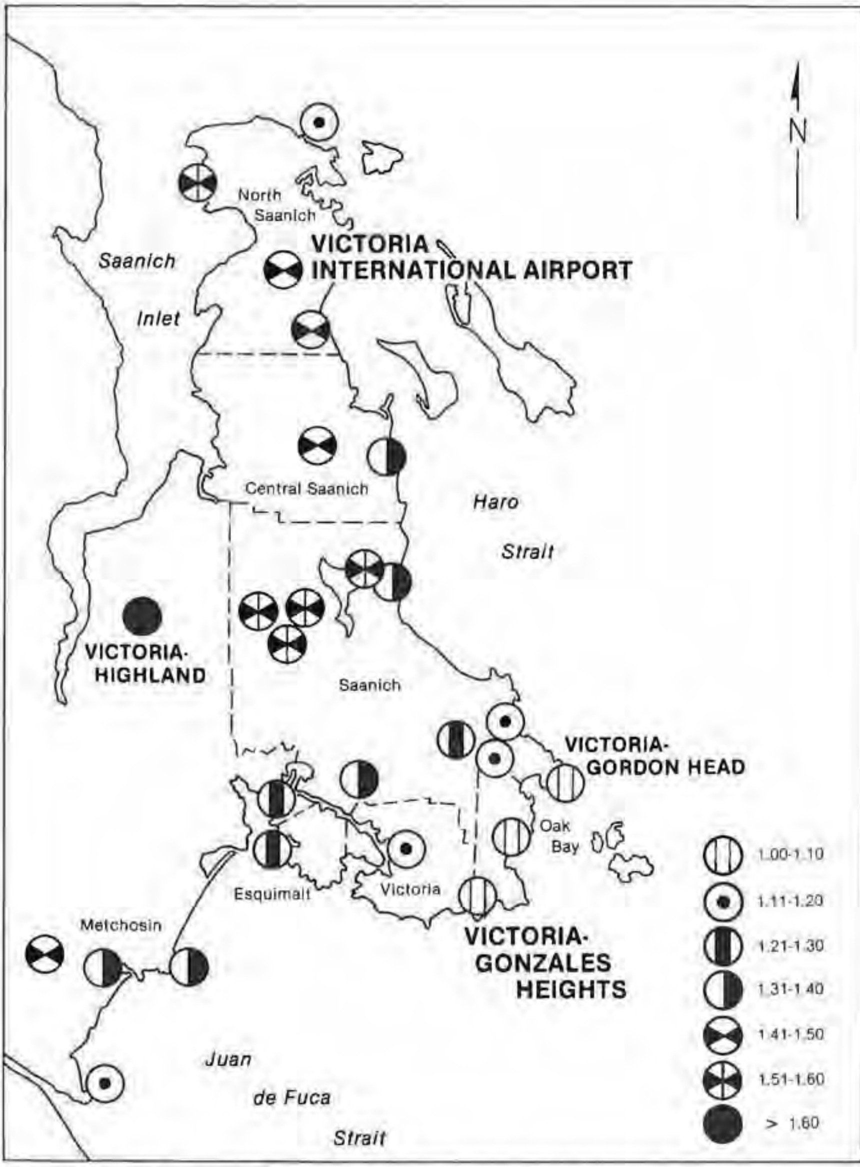

FIGURE 4. Median ratio of station to Victoria Gonzales Heights precipitation for storms when Victoria International Airport recorded more precipitation than Gonzales Heights.

map had a higher precipitation total at Gonzales Heights than at the Airport. Thus, although the composite pattern (Figure 5) is a combination of the two heavy precipitation patterns previously discussed, it is more reminiscent of that when Gonzales Heights has the heaviest precipitation (Figure 3).

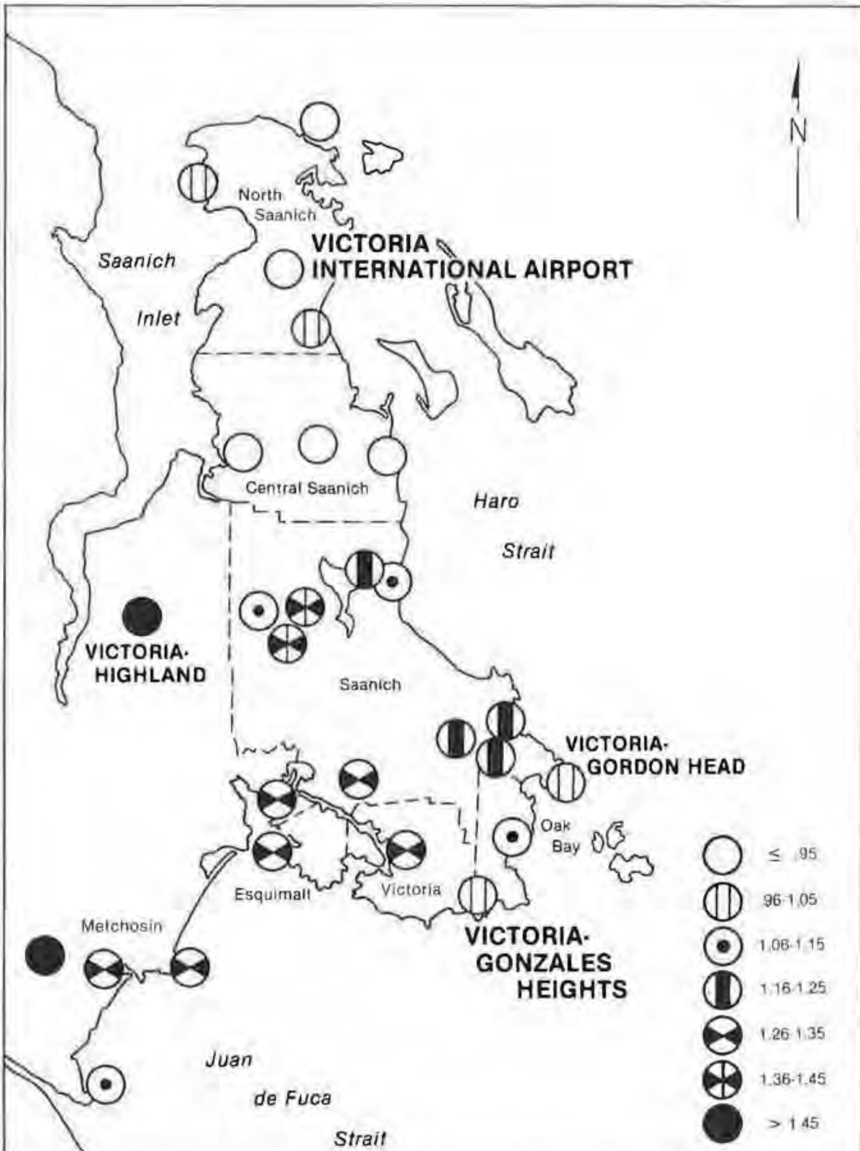

FIGURE 5. Composite map of the median ratio of station to Victoria Gonzales Heights precipitation for the 10 highest precipitation storms at two intermediate stations.

Precipitation increased both north and west from Gonzales Heights and reached a maximum of 50 percent more at the western stations (Figure 5). Another zone of low precipitation occurred in the central and northern portions of the Saanich Peninsula where values ranged from just slightly higher than those at Gonzales Heights to about 10 percent less.

A preliminary assessment was made in order to identify possible causes of the difference in the two distinct patterns of heavy precipitation in the Greater Victoria region. It must be cautioned that this is a preliminary discussion designed simply to indicate some plausible controls on the basis of their association with one or the other of the distinct patterns. It does provide a useful first step, however. Further analysis based on more complete data and focussing on the actual mechanisms of effect is a project for future research.

Hourly surface wind direction showed a great deal of variation but was primarily from the southeastern quadrant at the two major stations during most storms regardless of the precipitation distribution pattern. Thus, the differences in exposure to surface winds is not considered to be a major cause of the difference. The storms seemed to track from southwest to northeast and the centre of the low passed north of Victoria in most cases. Neither surface vapour pressure nor relative humidity, taken as measures of the relative available moisture and saturation of the air mass, showed any consistent pattern. The front type and age of the storm did differ somewhat between the two cases. Storms that brought more precipitation to Gonzales Heights seemed to be somewhat younger with more distinct warm and cold fronts. Those that produced higher totals at the Airport were farther into the occluded stage. Eight of the ten fronts that passed over Victoria during the "Airport–greater" storms were at least partially occluded, whereas only three of the 10 "Gonzales –greater" fronts could definitely be labelled as occluded. The front type did not produce a perfect differentiation of the storms into the two categories, however. Combinations of front type with other storm characteristics mentioned previously did not produce a perfect separation either. Given the difficulty of specifying front type from daily weather maps, however, some influence of front type cannot be ruled out.

The key factor that did the best job of differentiating the storms when Gonzales Heights had a greater precipitation from those during which the Airport had the greater total was upper air wind direction. The 500 mb wind was from the southwest quadrant during all but one storm when Victoria International Airport had the greater precipitation. It was from the northwest quadrant during all of the storms when Gonzales Heights had the higher total. The one storm that did not fit into the proper category on the basis of upper air wind direction was that of December 7 and 8, 1971. The Airport received the higher precipitation total despite the fact the upper air wind was from the west-northwest. The difference in precipitation between the two stations was not great. The Airport received only 5 percent (2.6 mm) more total precipitation on the day of the maximum. The total precipitation in this storm was composed of both rain and snow. Victoria International Airport reported 23.9 mm of rain and 24.4 cm of snow. Gonzales Heights recorded more rain than the Airport (34.0 mm) but much less snow (9.4 cm). The recording rain gauge data at the two stations showed higher intensity at Gonzales Heights for all periods from five minutes through 12 hours. Hourly air temperatures on the day of maximum precipitation did not show any important difference but the mean daily wind speed was much higher at Gonzales Heights (35.4 km/hr compared with 21.7 km/hr). Thus, it is quite possible that the higher wind speed at Gonzales Heights reduced the catch of precipitation, especially the snow, and a greater underestimate of total one-day precipitation, occurred at this station.

The precise reasons for the different precipitation patterns with northwest and southwest upper air flow are not known for sure. A couple of possibilities might be different patterns of orographic effects or convergence in the region. The recording rain gauge data from Gonzales Heights and the Airport generally reveals that the station with the highest one-day total precipitation also had a higher intensity for shorter time periods as well. The exception is the anomalous storm of December 7 and 8, 1971 discussed above. This would point to greater relative uplift or more humid air producing heavier precipitation in the locality of the station with the highest total. These data plus summary comments on the day's weather published in the *Monthly Meteorological Summary* indicate intensity of precipitation rather than duration had the dominant effect on differences between these two stations. Victoria Gonzales Heights is located only 27 km from Victoria International Airport. Differences in atmospheric water vapour would not be enough to cause the observed variation in storm precipitation. Thus, the factors that may influence the relative rates and/or levels of uplift would be the logical place at which to begin an analysis of reasons for the different distribution patterns.

Orographic effects should be somewhat reversed between southwest and northwest flow. The Gonzales Heights area is farther from the hills of Vancouver Island than is the northern Saanich Peninsula with southwesterly winds but is closer with a northwesterly. The rain shadow of the Olympic Mountains does not protect any part of the Greater Victoria region with a northwest wind and the southern part of the region is closer to the windward side of the range and better positioned to receive any precipitation building back upstream. Stations located south and east of Victoria on the north coast of the Olympic Peninsula usually received less precipitation than did Victoria Gonzales Heights during storms with a northwest wind, whereas those farther west out of the lee of Vancouver Island, usually received more. Thus, any contribution of uplift over the Olympic Mountains is problematical.

Assuming that lower level 850 mb or 700 mb winds approximate the 500 mb flow, the effects of convergence as these winds interact with the topography could potentially contribute to different precipitation distribution patterns with different flow directions.

4. SUMMARY

The distribution of precipitation is a subject that has long intrigued climatologists both for its own sake and because of its important practical significance. The distribution of heavy precipitation is an important subject in applied climatology. Most studies of heavy precipitation have looked at its temporal pattern at a particular station rather than its spatial distribution on the meso- or microscale. Studies that have looked at the distribution have most frequently addressed only one or two particularly severe storms rather than the climatology of intense precipitation.

Comments received from engineers during and after a seminar on stormwater management revealed that there is, indeed, a great deal of interest in the variation of heavy precipitation over small regions among those who have to design roads and structures to accommodate the precipitation. One reason for the lack of climatologies of heavy precipitation is that over much of Canada, where convective summer storms are responsible for most of the heavy precipitation events, the distribution can vary markedly from storm to storm. Areas where the distribution of heavy precipitation results from the interaction of large, mid-latitude cyclonic storms with orographic controls should show a more consistent pattern and lend themselves more readily to a climatology of heavy precipitation.

The rainfall intensity-duration frequency tables produced by the Hydrometeorology Division of the Canadian Climate Centre confirm the finding of this study that Gonzales Heights and the southeastern part of the Greater Victoria region can expect more intense storms than Victoria International Airport and the north. The Airport has higher rainfall intensity over 5, 10, 15 and 30 minute duration for return periods from two through 100 years. Gonzales Heights has the higher values for durations between one and 24 hours for the 50 and 100 year return periods and between two and 24 hours for the 5, 10, and 25 year return periods. Caution must be used when evaluating these comparisons, however, because of the marked difference in record length between the two stations.

This study has shown that it would be a great mistake to assume the distribution of heavy precipitation is always the same as that of the much better known distribution of annual total precipitation. The two basic patterns found in the Greater Victoria region seem to be most closely related to upper air wind direction although frontal type may also have some influence. The distribution pattern with southwesterly winds, the common upper air flow pattern during storms on the coast, resembled that of the annual precipitation. The relative differences between stations were augmented during the heavy precipitation events, however. A somewhat different distribution pattern resulted with northwesterly upper air flow.

The variation in heavy precipitation, like that of total precipitation, was great enough throughout the region that it would be imprudent to use the data from one station to represent the amount expected in another area. The present study has indicated the relative variation that might be expected across the region based on the available station network, but the precise microscale pattern throughout this area of varied topography will probably never be completely resolved. It is hoped, however, that the present study has increased our understanding of the precipitation climatology of the Greater Victoria region, highlighted some of the variation in distribution patterns that can occur, and stimulated interest in some of the possible controls of the two different patterns.

ACKNOWLEDGEMENT

The useful advice of Mr. Norm Dressler, his staff at the Victoria Weather Office, and Mr. Terry Duffy of the Gonzales Heights weather station during all phases of this study is greatly appreciated. The suggestions of Mr. Rodney Chilton helped improve an earlier version of this paper. The contribution of one of the referees who supplied the rainfall intensity – duration frequency data is also acknowledged.

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Synoptic Weather Conditions During the Porter Lake Experimental Fire Project

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ABSTRACT

During a series of fire behaviour tests in black spruce-lichen woodland near Porter Lake, Northwest Territories (107°88"W, 61°79"N) the last fire of the series escaped confinement and burned over 1430 hectares. This report investigates the synoptic weather conditions from June 27 to July 26, 1982, bracketing the test fire period.

It was found that strong surface winds on July 7, 1982, contributed to the escape of the fire. These unexpectedly strong and persistent winds resulted from a deep convective layer near the ground linking the surface wind to the lower extremity of an upper level jet stream. Such winds could not have been predicted without the help of an experienced weather forecaster.

RÉSUMÉ

Lors d'une série de tests visant à étudier le comportement du feu dans une forêt claire composée d'épinettes noires et de lichens près de Porter Lake dans les Territoires-du-Nord-Ouest (107°88"0., 61°79"N.), le dernier feu de la série n'a pu être contenu et s'est propagé sur 1430 hectares. Dans ce rapport, sont étudiées les conditions synoptiques du temps du 27 juin au 26 juillet 1982, intervalle comprenant la période des tests.

On a découvert que de forts vents de surface le 8 juillet 1982 ont contribué à la propagation de feu hors des limites fixées. Ces vents forts et persistants qui n'avaient pas été prévus sont dus à la formation près du sol d'une couche de convection profonde reliant le vent de surface à l'extrémité inférieure d'un courant-jet à haute altitude. De tels vents n'auraient pu être prévus sans l'aide d'un prévisionniste expérimenté.

1. INTRODUCTION

On July 7, 1982 an experimental fire ignited near Porter Lake, N.W.T. went out of control, burning over 1430 hectares before being declared extinguished on July 26, 1982. The behaviour of forest fires is dependent on the fire environment which includes the influences of topography, fuel and weather.

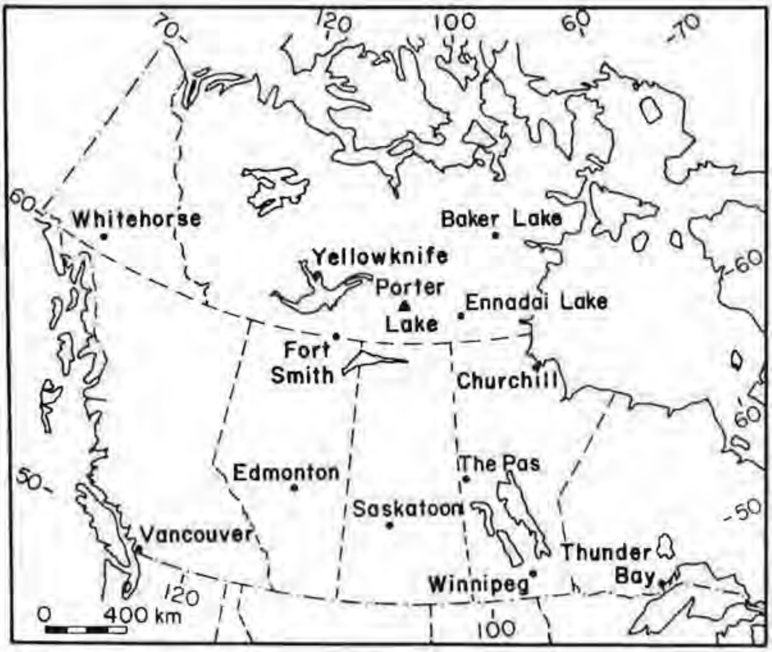

FIGURE 1. Western Canada.

This report investigates the weather conditions on the days preceding and during the escaped fire. Emphasis is placed on the wind, which appears to be the principal meteorological factor.

The escaped fire was last in a series of tests conducted by the Canadian Forestry Service (CFS) and Indian and Northern Affairs Canada (INAC) to investigate fire behaviour in the upland black spruce (*Picea mariana*) – open lichen (*Stereocaulon paschale*) woodland fuel type in the subarctic region of the Northwest Territories (Alexander *et al.* 1987). A suitable study area was found at Porter Lake in the Caribou Range (61°43'N 108°03'W), located 290 km northeast of Fort Smith and 350 km east-southeast of Yellowknife (Figure 1). This site lies within the Porter-Wignes Ecodistrict (Bradley *et al.* 1982) at an elevation of 425 m above MSL. The primary objective of the CFS/INAC experimental burning project was to ignite a series of small-scale test fires over a broad range of weather conditions and monitor the resulting fire behaviour characteristics. The resulting information was to be utilized in the development of a quantitative scheme of fire behaviour prediction for use by fire managers (Lawson *et al.* 1985).

Nine experimental fires were successfully conducted and documented over a fairly wide range of burning conditions as expressed by the Canadian Forest Fire Weather Index (FWI) System (Canadian Forestry Service 1984) during the afternoons between June 27 and July 7. Data from

TABLE 1. Sequence of test fires at Porter Lake, Northwest Territories*

Date	Test Fire	Ignition Time MDT	Rate of spread m min^{-1}	Comments
June 30	L1	1540	6	No control problems
July 1	L2	1529	26	Two spot fires (65 m jump distance) no control problems
July 5	L3	1405	4	No control problems
July 6	L4	1520	4	No control problems
July 7	L5	1517	33	Fire escapes plot at 1524 reaches a bay on Porter Lake at 1531 with average rate of spread 51 m min^{-1}

* Data from Alexander et al. (1987).

five experimental fires is shown in Table 1. It is clear that conditions on two of the test days produced rapid rates of fire spread and spotting in advance of the fire front. The burning plots varied from 0.02 to 0.65 ha in size. The final experimental fire which was ignited at 1517 MDT on July 7 inadvertently escaped the confines of the plot area and spread downwind in a southerly direction as a high-intensity, free-burning crown fire (Alexander *et al.* 1987) for nearly 4 km by 1735 MDT. Fire CR-6 attained nearly 55% of its final size of ≃ 1430 ha during the burning period on July 7.

2. DATA AND OBSERVATIONS

Meteorological data acquired for the period June 27 to July 26, 1982 included hourly surface observations for Fort Smith, Ennadai Lake, Fort Reliance, and Fort Resolution. Also included are two to three surface weather reports daily from forestry stations at Tsu Lake and Snowdrift. Upper air observations for Fort Smith, The Pas, Churchill, and Baker Lake, as well as satellite imagery for the period July 6 and 8 are also examined. In addition, selected surface and upper air analyses were obtained.

A weather station established June 26, 1982 at Porter Lake was equipped with a Forest Technology Systems Fire Weather Station 6100-24. The station included a Downeaster model WV II Type 2 anemometer, a Downeaster model WV I Type 1 vane, a hygrothermograph, Goertz fan ventilated psychrometer, Taylor Clear-Vu plastic rain gauge, and a bi-metallic actinograph. A 10 minute average wind speed was measured at Porter Lake at 10 meters above the ground in a forest clearing whose diameter was five times the tree height. This speed should equal 60% of that observed at an airport site (Oliver 1974, Silversides 1978, Simard 1969, Turner and Lawson 1978). During the test fires, additional observations of maximum gust speeds were taken every two minutes.

TABLE 2.

Noon meteorological observations and components of the Canadian Forest Fire Weather Index (1984 version) at Porter Lake, N.W.T., 1982.*

Starting Values: 85-FFMC 47-DMC 175-DC

Date M	Date D	Temp °C	RH %	WS KM/H	RAIN† MM	WD	FFMC	DMC	DC	ISI	BUI	FWI	DSR
6	27	17.8	36	10.0	0.0	NE	88	50	182	5.5	59	15	3.43
6	28	17.7	41	0.5	0.0	S	88	53	188	3.5	62	11	1.94
6	29	22.2	32	7.1	0.0	SE	90	57	196	6.4	66	18	4.71
6	30	25.9	36	13.0	0.0	S	91	62	204	9.2	70	24	7.84
7	1	26.3	26	18.1	0.0	SE	93	67	212	15.6	75	36	15.38
7	2	16.2	74	9.1	2.8	E	63	54	219	0.6	67	2	0.08
7	3	20.1	65	3.2	2.7	NE	60	46	226	0.4	61	1	0.02
7	4	19.0	61	18.9	0.0	NE	77	48	233	2.4	63	8	1.10
7	5	18.9	25	18.2	0.0	NE	89	51	240	8.8	67	23	7.04
7	6	19.4	42	13.0	0.0	NE	89	54	247	6.8	70	20	5.34
7	7	27.4	35	18.1	0.0	NW	91	59	256	12.2	75	30	11.54
7	8	25.1	35	6.0	0.0	SW	91	63	264	6.6	79	21	5.77
7	9	23.8	52	12.2	0.0	N	90	65	272	8.0	82	24	7.54
7	10	19.5	43	11.8	3.8	E	73	50	272	1.2	68	4	0.39
7	11	15.8	46	6.4	0.0	NE	82	52	279	2.0	71	8	0.99
7	12	18.7	37	4.6	0.0	SW	87	55	286	3.5	74	12	2.31
7	13	20.1	51	12.3	0.0	SW	87	57	293	5.3	77	17	4.20
7	14	23.2	33	12.3	0.0	N	90	61	301	8.1	81	24	7.62
7	15	14.7	46	15.3	0.0	NE	89	63	307	8.5	83	25	8.30
7	16	18.8	33	4.0	0.0	SW	90	66	314	5.2	87	18	4.67
7	17	22.7	39	10.8	0.0	SW	90	70	322	7.4	90	24	7.47
7	18	17.7	65	17.4	0.0	SW	88	71	329	7.7	92	25	8.01
7	19	10.1	79	4.7	21.0	NW	37	31	268	0.1	48	0	0.00
7	20	9.7	81	8.0	12.0	NW	34	14	241	0.1	25	0	0.00
7	21	10.1	79	14.7	0.5	NW	53	15	247	0.5	26	0	0.01
7	22	24.9	36	11.8	0.0	SW	83	19	255	3.1	32	7	0.79
7	23	19.5	60	13.0	0.0	NE	84	21	262	4.0	35	9	1.28
7	24	22.6	46	11.3	0.0	E	87	24	270	5.3	39	12	2.19
7	25	21.7	59	11.7	0.0	W	87	26	278	5.4	42	13	2.43
7	26	22.6	48	9.4	0.0	NW	88	29	286	5.1	46	13	2.47

* Data from Alexander et al. (1987). † 24 hour ending at 1300 MDT.

NOTES

The FWI is comprised of three moisture codes and two intermediate codes. The three moisture codes represent the moisture content of fine fuels (Fine Fuel Moisture Code, FFMC), loosely compacted duff (Duff Moisture Code, DMC), and compact organic soil (Drought Code, DC). The two intermediate indices, which are derived from the moisture codes and the surface wind, indicate the rate of initial fire spread (Initial Spread Index, ISI) and total available fuel (Build Up Index, BUI). The two intermediate indices are combined to obtain the FWI which represents the intensity of the spreading fire. The Daily Severity Rating (DSR) is an exponential function of the FWI designed to explain the rapid increase of area burned with fire size. WS = wind speed. WD = wind direction.

TABLE 3. Summary of weather conditions, fire danger ratings, and fire behaviour characteristics during the experimental fires – Porter Lake project.*

Fire	Date	Time of fire (MDT) start	Time of fire (MDT) end	Dry-bulb temperature (°C)	Relative humidity (%)	Wind speed (km/h)	CFFWI components FFMC	DMC	DC	BUI	FWI	ISI	Rate of spread (m/min)
						LINE SOURCE IGNITION FIRES							
L1	June 30	1540	1554	26.5	30	20.4	92.1	62	204	71	37	16.1	6.1
L2	July 1	1529	1537	24.5	25	24.0	92.8	66	212	74	45	21.3	26.3
L3	July 5	1403	1428	20.0	28	17.0	89.4	51	240	67	24	9.3	3.5
L4	July 6	1519	1542	21.5	36	14.5	90.1	55	247	71	25	9.1	3.7
L5	July 7	1517	1524	27.5	31	28.0	92.0	59	256	75	48	23.5	33.3
L5A†	July 7	1524	1531	27.5	31	34.6	91.9	59	256	75	59	32.9	51.4

* Data from Alexander et al. (1987). † Between end of Plot L5 and bay of Porter Lake.

TABLE 4. Porter Lake weather extremes June 27-July 17.*

Date		Temperature Max	Temperature Min	RH Max	RH Min	Wind Speed Max
		°C		%		km/h
June	27	19	3	80	34	13
	28	23	7	78	29	12
	29	24	10	63	21	14
	30	26	12	58	29	21
July	1	27	13	71	23	23
	2	18	12	100	66	15
	3	23	11	90	41	13
	4	22	8	80	48	21
	5	21	7	76	25	16
	6	22	3	80	34	17
	7	28	8	75	29	35
	8	26	13	78	32	†
	9	23	11	90	43	†
	10	20	†	†	37	14
	11	17	11	63	40	11
	12	21	8	74	26	9
	13	23	10	68	33	14
	14	26	11	68	23	15
	15	18	6	73	40	17
	16	22	4	93	24	14
	17	24	10	66	28	15

* Data from Alexander et al. (1987). † missing data
Weather observed once a day at 1300 MDT after July 17.
Precipitation for July 18-July 26 are in Table 2.

While the study was in progress the FWI (see footnote Table 2) (Van Wagner 1974) was calculated on a daily basis. All components of the FWI, along with the Daily Severity Rating (DSR) and meteorological observations from noon local standard time, are given in Table 2. A summary of weather conditions, fire danger ratings, and fire behaviour characteristics for each experimental fire was prepared at the fire site by personnel of the Canadian Forestry Service (CFS) (Table 3). Pertinent meteorological extremes during most of the study period are given in Table 4.

The upper air flow

During the latter part of June 1982 the upper level pressure pattern over western Canada was dominated by a high-latitude block (Figure 2). On June 27 a warm high over the southern Yukon was directly north of a cold low located off the coast of southern British Columbia. This pressure pattern resulted in a northerly upper air flow over Porter Lake. By July 1 the high had moved eastward to the Mackenzie River valley and the cold low had moved southeastward into Nevada (Figure 3). During the next few days a series of

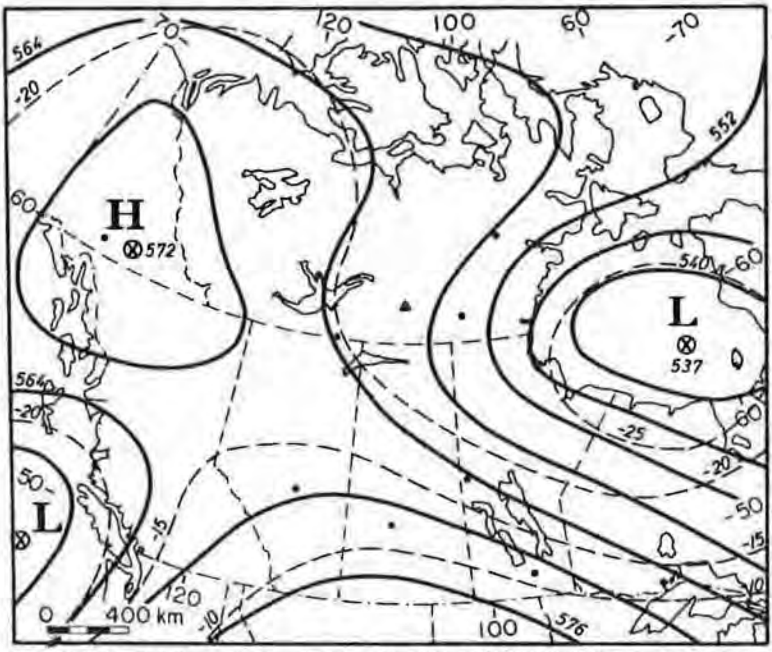

FIGURE 2. 50 kPa analysis valid June 27, 1982, 1800 MDT. Units are decameters (heights, solid line) and °C (temperature, dashed line).

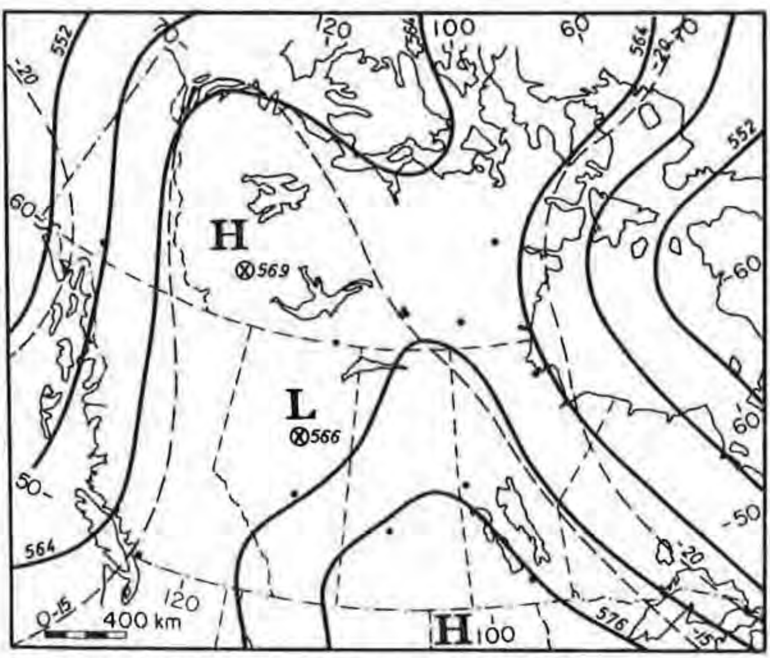

FIGURE 3. 50 kPa analysis valid July 1, 1982, 0600 MDT. See Fig. 2.

lows moved into the Washington-Oregon coast, and thence northeastward into the central Alberta-Saskatchewan border area. By July 5 the high was centered over Great Bear Lake, with a low remaining quasi-stationary near the Alberta-Saskatchewan border. A cold pool of air and associated low moved to Wager Bay, located 300 km northeast of Baker Lake (Figure 4). On July 6 the low in Saskatchewan drifted slowly eastward re-forming the familiar omega block shape. The Wager Bay cold low moved south over Western Hudson Bay (Figure 5). Associated with this upper air pressure pattern was a north-south jet stream extending from Victoria Island to eastern Great Slave Lake. The cold low over western Hudson Bay strengthened and drifted southward to lie just east of Churchill, Manitoba by July 7 (Figure 6). During the same day the jet stream shifted eastward to lie in a north-south line just east of Porter Lake. On July 8 the cold low moved southeast along with the 'main pulse' of the jet stream (Figure 7). The blocking ridge remained as the dominant feature in the upper level pressure pattern until July 19 when a cold low from the Gulf of Alaska moved into the southern Mackenzie District.

The surface weather pattern

At the surface a north-south ridge of high pressure over the Porter Lake area on June 27 (Figure 8) proceeded slowly eastward. The resulting moderate southerly flow of warm dry air persisted until July 1 (Figure 9). The warm dry weather came to an end as the easterly flow around a quasi-stationary low pressure area located near the central Alberta-Saskatchewan border brought cooler and moister conditions to the southern Mackenzie District. Further north, a high pressure ridge extended southward to Great Slave Lake creating a moderate east to northeast flow over the Porter Lake site (Figure 10). On July 5 and 6 this area of high pressure moved southward to the Great Slave Lake area, resulting in a decreasing pressure gradient over Porter Lake (Figure 11). By July 7 the high had moved to southern Saskatchewan with a weak ridge extending northward to Great Slave Lake, allowing the surface pressure gradient to remain weak (Figure 12). During the same period the low moved from central Saskatchewan eastward to northwestern Ontario while another surface low over western Hudson Bay was gradually deepening and moving southward. The Hudson Bay low continued to intensify as it moved to a position just northeast of Churchill. The extreme cold of this low, in contrast to the warm air associated with the ridge near Porter Lake created a strong temperature gradient across the intervening area. It was this extreme temperature contrast, both at the earth's surface and aloft, which led to the development of strong surface winds during the last experimental fire.

3. DISCUSSION

Strong surface winds were an important factor in spotting ahead of the Porter Lake fire and in its ultimate escape. On the basis of the test fire days at

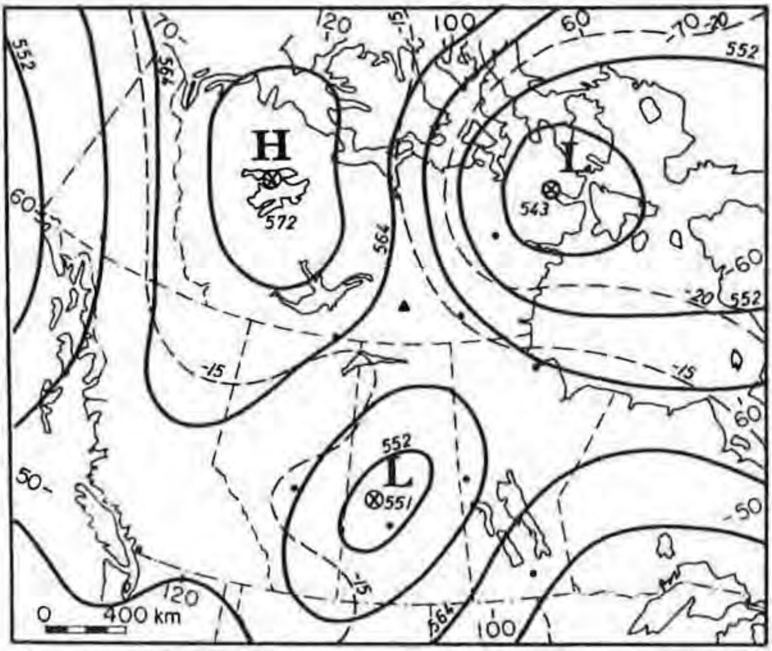

FIGURE 4. 50 kPa analysis valid July 5, 1982, 0600 MDT. See Fig. 2.

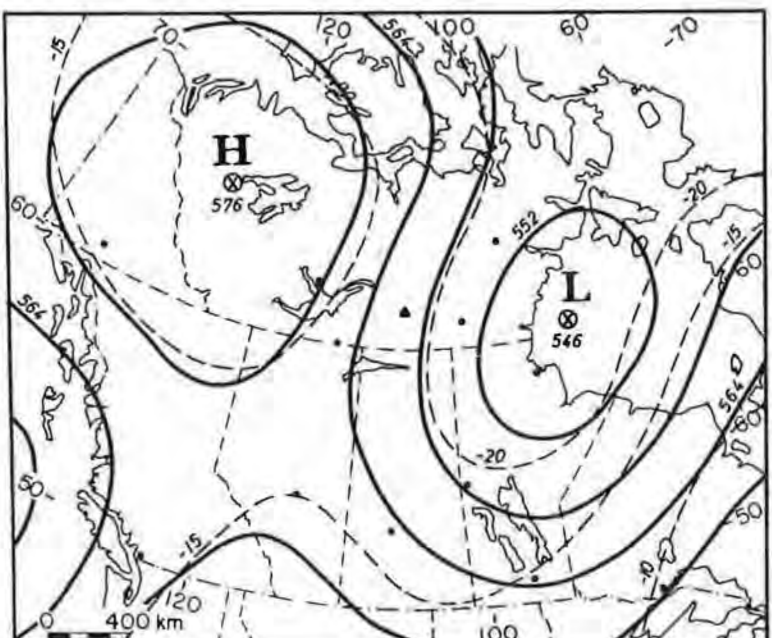

FIGURE 5. 50 kPa analysis valid July 6, 1982, 1800 MDT. See Fig. 2.

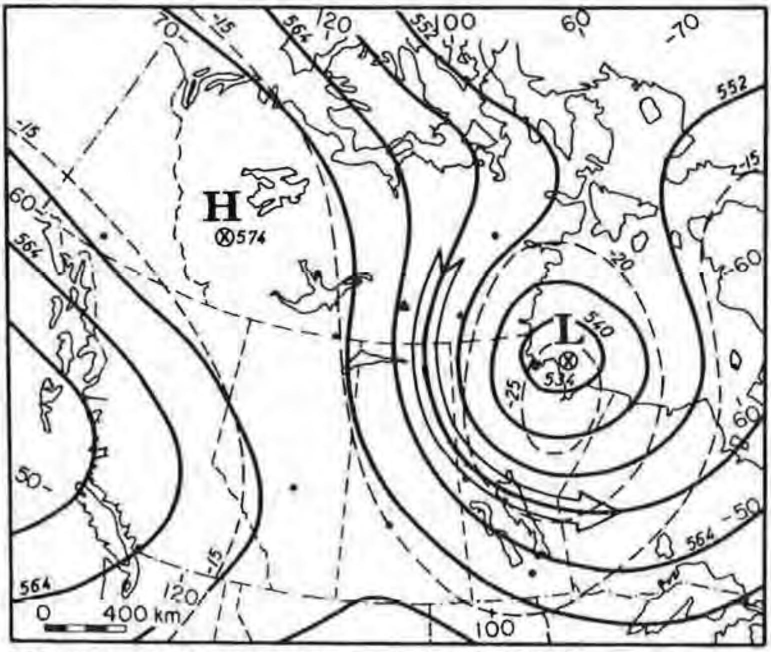

FIGURE 6. 50 kPa analysis valid July 7, 1982, 1800 MDT. The arrow indicates the location of the jet core. See Fig. 2.

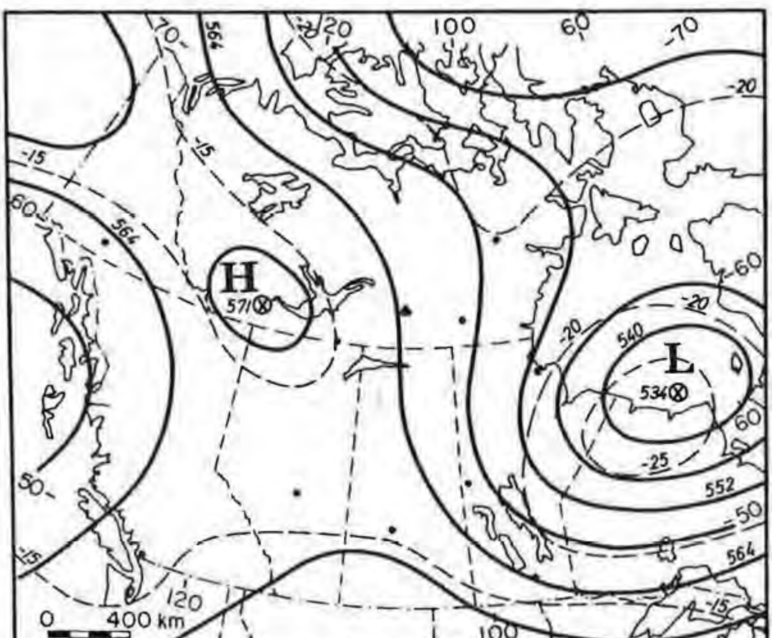

FIGURE 7. 50 kPa analysis valid July 8, 1982, 0600 MDT. See Fig. 2.

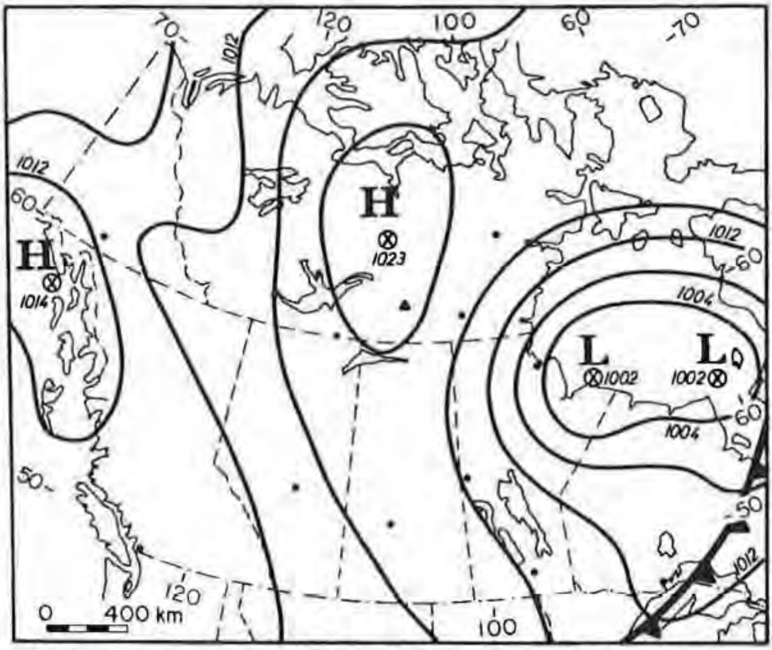

FIGURE 8. Surface analysis valid June 27, 1982, 1200 MDT. Units are millibars (1 kPa = 10 millibars).

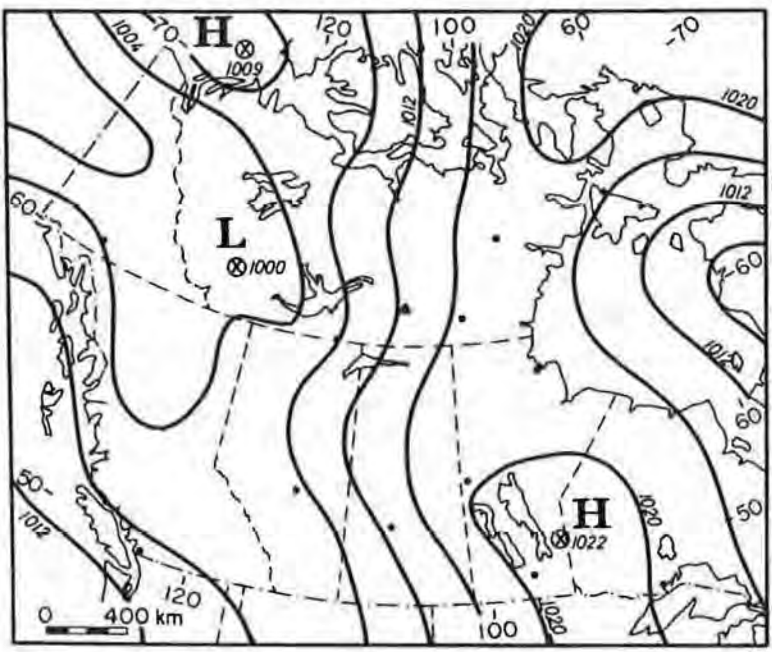

FIGURE 9. Surface analysis valid June 30, 1982, 1800 MDT. See Fig. 8.

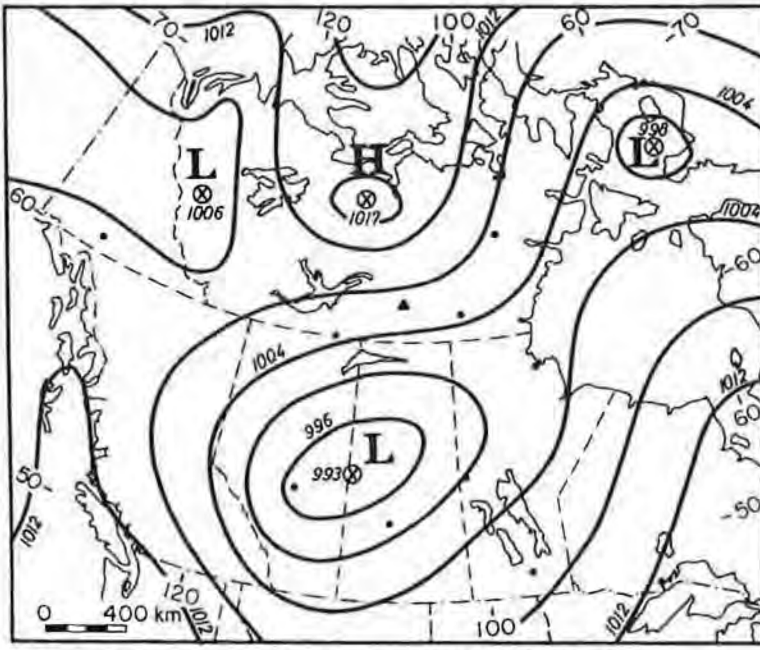

FIGURE 10. Surface analysis valid July 4, 1982, 1200 MDT. See Fig. 8.

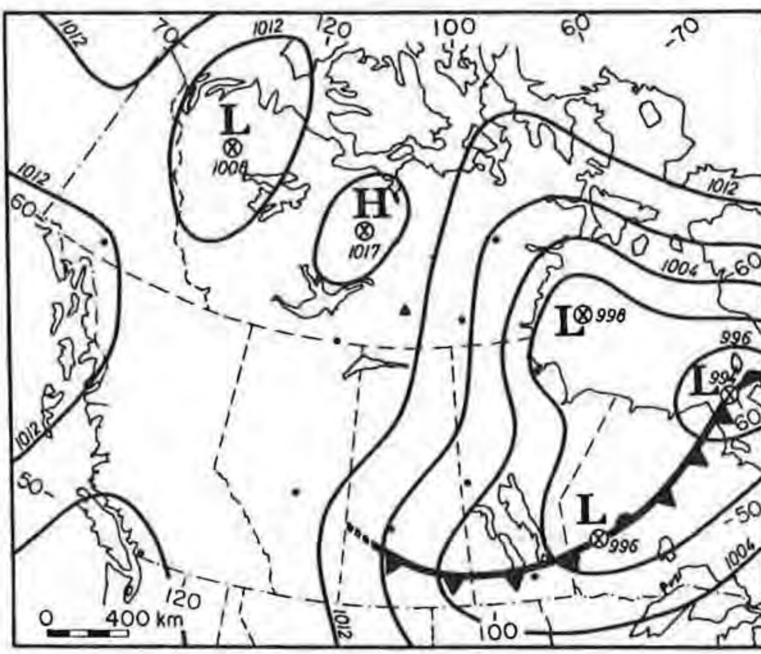

FIGURE 11. Surface analysis valid July 6, 1982, 1200 MDT. See Fig. 8.

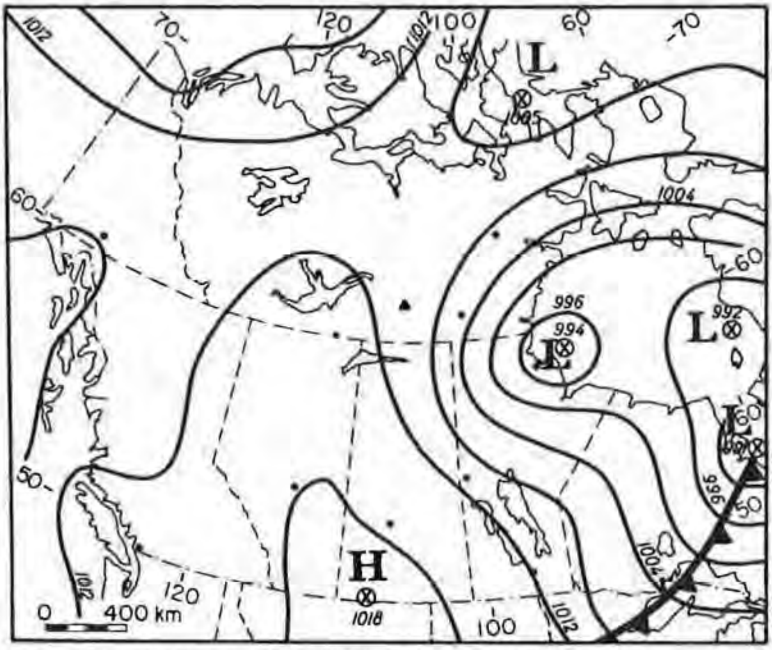

FIGURE 12. Surface analysis valid July 7, 1982, 1200 MDT. See Fig. 8.

Porter Lake it is evident that, for the fuel type present, spotting occurred when the Initial Spread Index (ISI) exceeded 20 (Table 1 and Table 3). Spotting occurred 100 m in advance of the escaped fire on July 7. These distances and the lack of spot fires on other days were likely a consequence of variations in the fuel moisture and the wind as reflected in the ISI. Of these two variables, wind is by far the more volatile and the more likely cause of unexpectedly large fluctuations in fire spread rate.

Strong surface winds in the Canadian Northwest are usually caused by a strong pressure gradient associated with the passage of a shortwave trough or upper low. The relationship of shortwave troughs to major fire runs has been documented by Brotak (1977).

Another cause of strong surface winds is the normal coupling of winds aloft with surface winds by the action of thermal convection. This effect may be particularly strong in the presence of a low level jet. The increased risk of extreme fire conditions when the wind profile is characterized by a low level jet has been noted by Byram (1954). Brotak (1977) found a vertical wind profile exhibiting a vertical wind shear with strong surface winds (Figure 13) to be characteristic of most major fire situations in the eastern United States. Brotak also found that one-third of major wildland fires had a low level wind maximum.

Before commencing to discuss the conditions leading to rapid fire

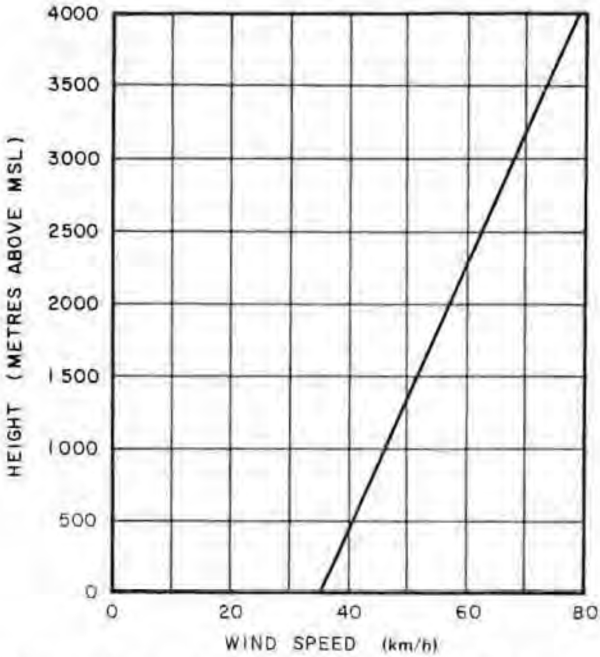

FIGURE 13. Vertical wind profile found by Brotak to be characteristic of most major fire situations in the Eastern United States.

spread on July 1 and July 7, 1982, it is important to note that dry fuel and strong winds were not the only factors involved. Differences in the plot size, configuration and location along with differences in the ignition pattern could have played a role in the escape of the test fire ignited on July 7.

A low level jet appears to have been the major factor in the rapid fire spread and spotting on July 1. On the previous day, June 30, the wind was light during the early morning hours despite a moderate surface pressure gradient (Figure 9). Nocturnal cooling had stabilized the surface layer of air and uncoupled it from the geostrophic wind aloft. By early afternoon the air near the ground had been heated sufficiently to cause active convection. As the afternoon progressed thermal convection extended through the nocturnal inversion linking the surface wind to the geostrophic wind aloft. The maximum wind speed at the ground reached 21 km h^{-1} at 1700 MDT. By 2100 the reduction in incoming solar radiation had reduced the level of convective activity and the wind had dropped to 4 km h^{-1}.

On July 1 the pressure gradient was similar to that of June 30 but a low-level southeasterly jet centered at 1.5 km with a maximum speed of 50 km h^{-1} was present, as shown by the 0600 MDT Fort Smith wind profile (Figure 14). Decreasing winds above the jet were caused by an opposing thermal wind above the jet core. In this case the opposing thermal wind was

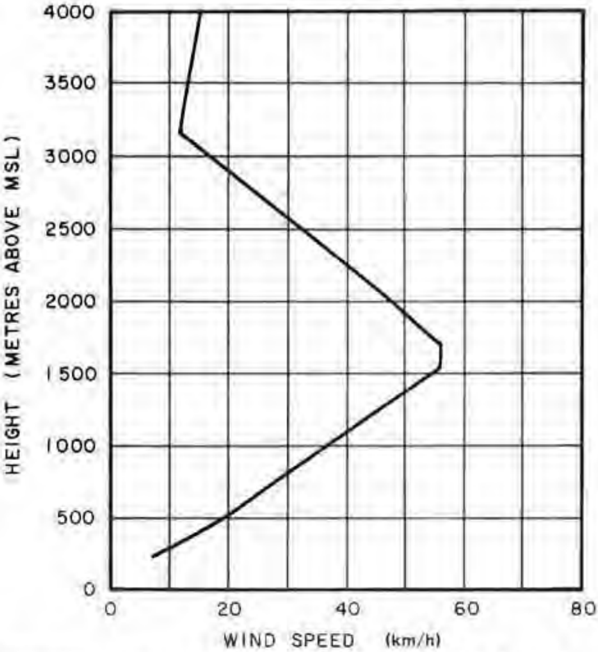

FIGURE 14. Vertical wind profile at Fort Smith, July 1, 1982, 0600 MDT.

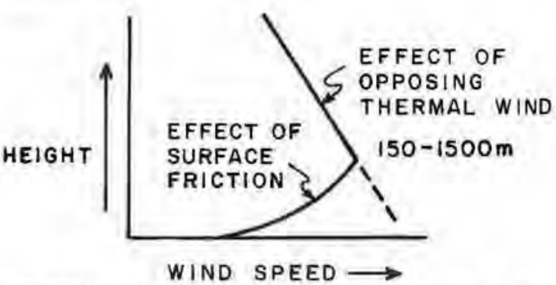

FIGURE 15. Vertical profile of the wind velocity resulting from the interaction of surface friction and an opposing thermal wind (from Dickison and Neumann 1982).

brought about by significantly colder air to the northeast of Great Slave Lake. The resulting wind profile, similar to Byram's type 2a (although located higher above the ground), is one of the most dangerous from a fire control standpoint. Its structure has been illustrated by Dickison and Neumann (1982) (Figure 15).

The development of the surface wind on July 1 was similar to that on June 30, except that the presence of the low level jet caused surface winds to reach 23 km h^{-1}. These winds in combination with an additional day of drying were sufficient to cause the fire rate of spread to reach 26 m min^{-1} and spotting to jump 65 m ahead of the fire front.

Experimental fires were ignited on July 5 and 6 respectively, during a period of weak pressure gradient (Figure 11). Despite considerable instability during the afternoon hours, the absence of strong winds aloft led to light to moderate surface winds. These winds combined with higher fuel moisture brought about by the lingering effects of precipitation on July 2 and 3 (Table 2) resulted in there being no fire control problems.

July 7 appeared to be an equally fine day for the final experimental fire. The day was clear and hot with low relative humidities. The high temperatures were accompanied by a northwest flow as air moved in a clockwise motion around the warm ridge west of Porter Lake (Figure 12). The low relative humidities were a result of a balance between moisture added by evapotranspiration and subtracted by condensation on the still cold lakes. (The lakes had been ice covered only two to three weeks earlier). During the afternoon the winds increased to 35 km h^{-1} and spotting occurred 100 m ahead of the fire front. Finally the fire escaped control, jumped across a small bay on Porter Lake and eventually burned an area of over 1430 ha.

To help visualize the vertical wind structure over Porter Lake on July 7 a vertical cross-section of the atmosphere between Fort Smith, N.W.T.

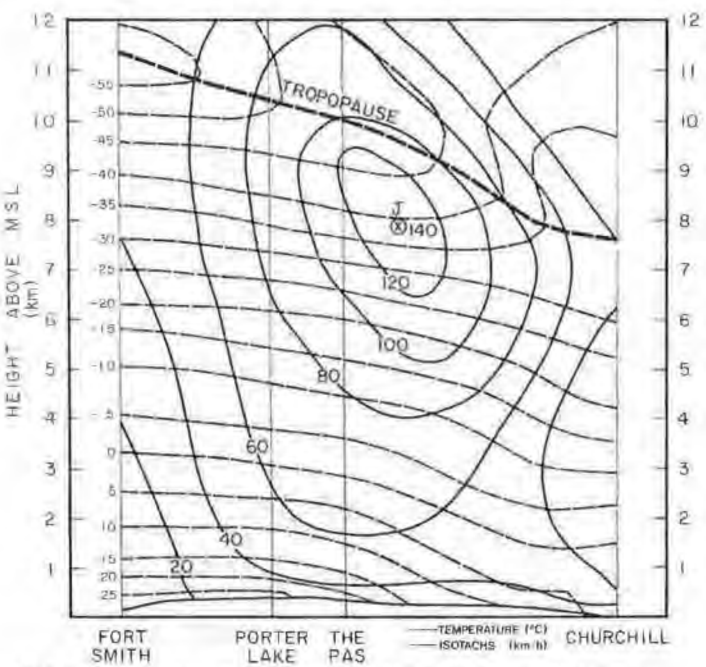

FIGURE 16. Vertical cross-section Fort Smith-Churchill, July 7, 1982, 1800 MDT.

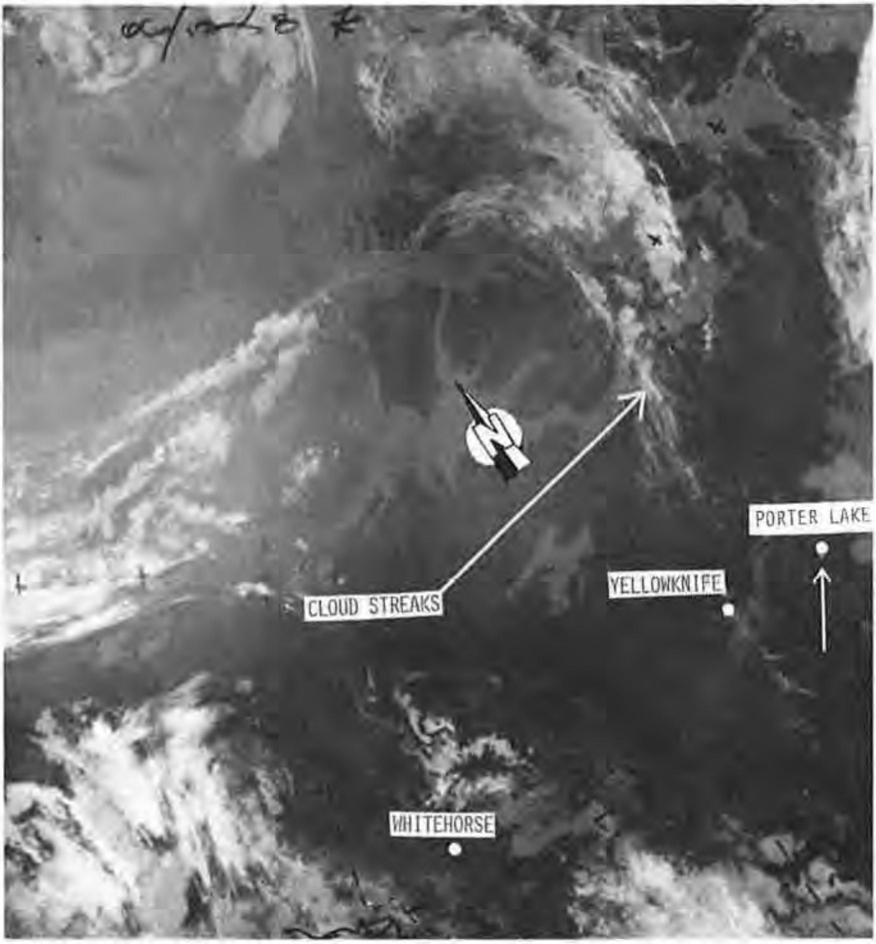

FIGURE 17. Infrared satellite imagery taken by NOAA-7 at 0700 MDT, July 6, 1982.

and Churchill, Manitoba has been constructed (Figure 16). Because of the paucity of upper air stations in the area, observations from The Pas, Manitoba have been displaced northward along the 50 kPa contour line through The Pas to a position where the same contour line intersects the cross-section. Using the thermal wind relation, a cross-section was drawn in which the increase of wind with height and the slope of the isotherms form a consistent picture. According to this cross-section a basically northerly jet core centered near 8 km lies just to the east of Porter Lake (Figure 16). Strong winds associated with this jet extend down to within a short distance of the earth's surface.

Corroboration of the jet location can be found in satellite imagery. Figure 17 is an infrared satellite picture from NOAA-7 taken at 0700 MDT, July 6. The cirrus cloud streak extending south-southwestward from

FIGURE 18. Enhanced infrared satellite imagery taken by NOAA-7 at 1500 MDT, July 7, 1982.

southeastern Victoria Island corresponds to tne position of the jet stream. Analysts have shown that the jet core lies just to the cold side (east in this case) of the cirrus (Weldon 1979). A second NOAA-7 infrared picture taken at 1500 MDT, July 7, shows a band of somewhat diffused cirrus extending in a north-south line through Porter Lake (Figure 18). A clearing zone in northern Saskatchewan and Manitoba represents the most advanced downstream position of the jet core (Weldon 1979). The July 7 satellite infrared picture also shows thunderstorm development south of Porter Lake, indicating extreme atmospheric instability at that time.

Using all available information, including upper air charts, tephigrams, and satellite imagery the most probable location of the jet core at 1800 MDT on July 7 is shown in Figure 6. A vertical wind profile over Porter

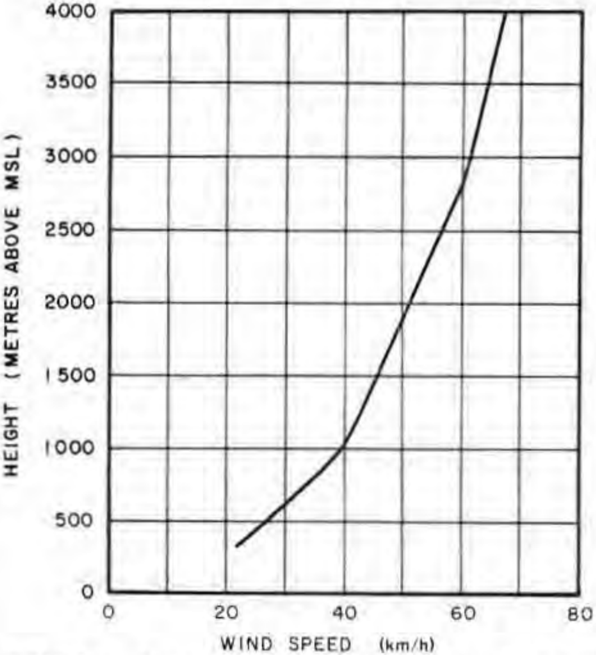

FIGURE 19. Postulated vertical wind profile at Porter Lake, July 7, 1982, 1800 MDT.

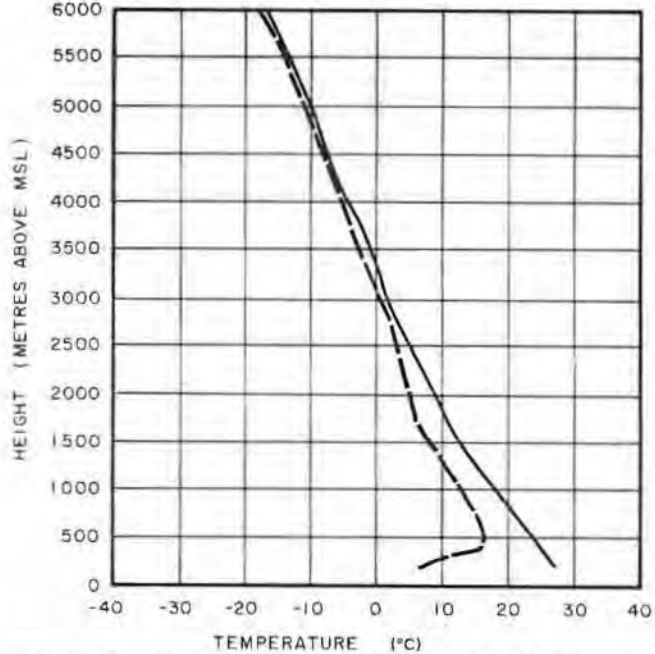

FIGURE 20. Vertical temperature profiles at Fort Smith July 7, 1982, 0600 and 1800 MDT. The dashed line represents the 0600 MDT profile and the solid line represents the 1800 MDT profile.

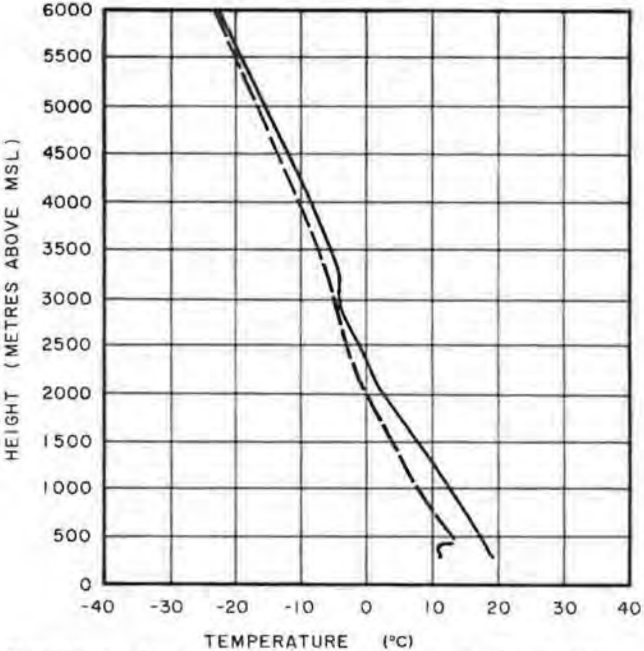

FIGURE 21. Vertical temperature profiles at The Pas July 7, 1982, 0600 and 1800 MDT. The dashed line represents the 0600 MDT profile and the solid line represents the 1800 MDT profile.

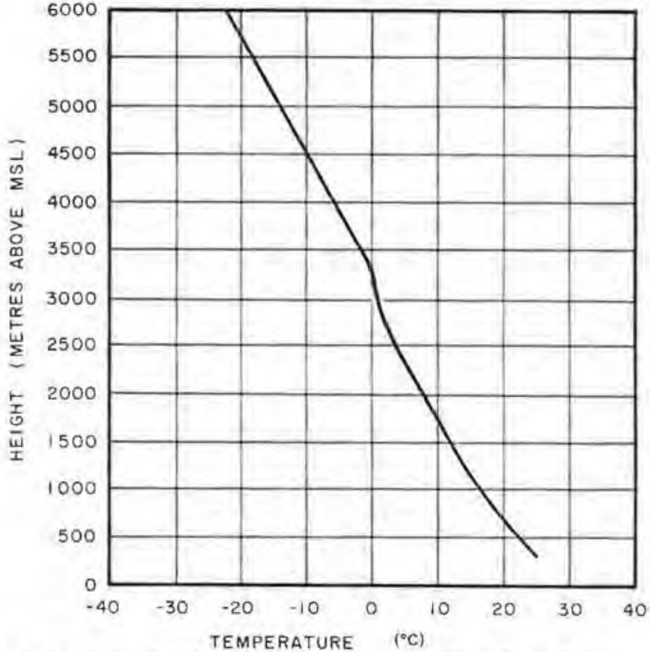

FIGURE 22. Postulated vertical temprature profile at Porter Lake, July 7, 1982, 1800 MDT.

Lake for 1800 MDT July 7, deduced from the same information is shown in Figure 19. This profile bears a remarkable resemblance to the situation in Figure 13 which Brotak found present in most major fire situations over the eastern United States. One feature of Figures 13 and 19 is the strong vertical shear of the wind in the lower atmosphere.

It has been mentioned earlier that vertical mixing is required to bring strong upper winds to the ground. Evidence for strong thermal instability was provided by the appearance of thunderstorms in the NOAA-7 imagery. Further evidence is provided by the radiosonde ascents from Fort Smith and The Pas (Figures 20 and 21). The 1800 MDT temperature profiles from both stations show a superadiabatic lapse rate from the ground to 1.7 km and strong instability extending to 3 km. A vertical temperature profile for Porter Lake at 1800 MDT (Figure 22) constructed from the cross-section (Figure 16) also depicts atmospheric instability close to the ground.

The test fire was ignited at 1517 MDT on July 7, 1982. A combination of factors, including relatively dry fuel and strong surface winds, caused the fire to spread rapidly (33 m min^{-1}). The fire jumped a sprinkler line at the end of the test plot at 1524 MDT. It advanced toward a 100 m wide bay on Porter Lake at an increased speed of 51 m min^{-1}, jumped the bay and became Caribou Range fire 6 (CR6). Tree-crown streets were observed in the immediate area of fire escape which suggests the presence of horizontal roll vortices as discussed by Haines (1982). Wildfire CR6 pushed rapidly southward on July 7, slowed dramatically on July 8 and 9, and continued with flare-ups on July 12 and 17 until finally declared out on July 26. The total area burned was 1430 ha.

4. CONCLUSIONS

Strong surface winds were a major factor in the escape of the Porter Lake, N.W.T. experimental fire ignited on 7 July, 1982. The purpose of the experiment was to test fire behaviour in this type of forest under the widest possible range of conditions, and from this point of view the experiment was a success. The unusual winds were caused by the coupling of the surface wind with a jet stream aloft through the action of strong thermal convection. These winds were a result of synoptic scale processes and could have been predicted through careful examination of the data by an experienced weather forecaster.

ACKNOWLEDGEMENTS

The authors wish to acknowledge with thanks the help of personnel from the western region of the Atmospheric Environment Service who supplied surface and upper air analyses, tephigrams, hourly surface observations, and satellite imagery. Thanks are also due to the Fort Smith Regional Fire Centre of Indian and Northern Affairs Canada for the provision of surface observations from nearby forestry towers. Mr. M. Alexander of the Northern Forest Research Centre, Canadian Forestry Service, provided meteorological and other pertinent data from Porter Lake, and valuable insight.

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Summary and Highlights of the 1984 Severe Local Storm Season

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ABSTRACT

This report provides an overview and summary of the 1984 severe local storm season in the broad region from the Rocky Mountains to Québec. Storm statistics were compiled from the seasonal report prepared by each of four Atmospheric Environment Service regions, and are summarized in tabular form. Highlights of the season are presented from an overall point of view and also by region.

RÉSUMÉ

Ce rapport donne un perspective global et un sommaire du temps violent estival de 1984 dans la vaste région du Canada des montagnes rocheuses jusqu'à Québec. On a compilé les statistiques des orages du rapport saisonal qu'on préparait à chaqu'un des quatre régions de la service d'environnement atmosphérique (SEA), et on les disposait en tableaux. On présente generalement les clous de la saison et on les présente aussi par région de la SEA.

1. INTRODUCTION

This report has been compiled mainly from information contained in the annual reports of the 1984 severe local storm season prepared by the Atmospheric Environment Service weather centres in 4 regions (Western, Central, Ontario, and Québec). The purpose is to summarize the statistics of the season and place them in an overall perspective, and to present seasonal highlights in narrative form.

The statistics should be interpreted with care because the definition (Table 1) of what constitutes a convective severe local storm varies from region

[1] Canadian Climate Centre, Downsview
[2] Ontario Weather Centre, Toronto
[3] Prairie Weather Centre, Winnipeg
[4] Alberta Weather Centre, Edmonton
[5] Centre météorologique du Québec, Montréal

TABLE 1. Regional Definitions of a Severe Convective Weather Event

WESTERN REGION

1) tornado, waterspout, or funnel cloud;
2) hail ≥ grape-size (12 mm);
3) wind gusts ≥ 100 km/h;
4) rainfall amounts ≥ 25 mm in one hour.

The observation of any of the above conditions, singly or together is necessary for an event to be labelled severe. Some subjective screening is required to eliminate synoptic scale wind events.

CENTRAL REGION

1) tornadoes or waterspouts;
2) hail ≥ 20 mm;
3) wind speeds or gusts ≥ 100 km/h;
4) rain amounts ≥ 50 mm within one hour.

ONTARIO REGION

1) tornado;
2) hail > 10 mm diameter;
3) damaging thunderstorm wind gusts or, if winds measured, gusts > 80 km/h (44 kts);
4) flooding downpours.

QUEBEC REGION

Objective criteria:

1) tornado;
2) hail ≥ 15 mm diameter;
3) strong gusts ≥ 83 km/h (45 kts);
4) heavy downpour ≥ 25 mm/h or, ≥ 50 mm/24h.

Subjective criteria:

- report of material damage or loss of life or injury caused by strong winds or heavy downpours.

to region and therefore, strictly speaking, the statistics are not comparable from one region to another. However, because the definitions are somewhat similar, the numbers do approximate the picture across part of the country. Counting the number of events is also a problem which is approached differently from region to region (see Section 2). Although a "national" summary is provided (Table 2), it does not include information from Canada's north, much of British Columbia, or from the Atlantic Provinces. Some severe local storms are known to occur each year in these regions, but a systematic record of them is not maintained, and indeed, in some areas is impossible to compile due to lack of information. A map of the four regions is given in Figure 1, and it can be seen that they cover the part of Canada most susceptible to such storms.

2. RECORDING AND COUNTING EVENTS

From a climatological point of view one would like to know the number of severe local storms obtained by treating each observation of a phenomenon as

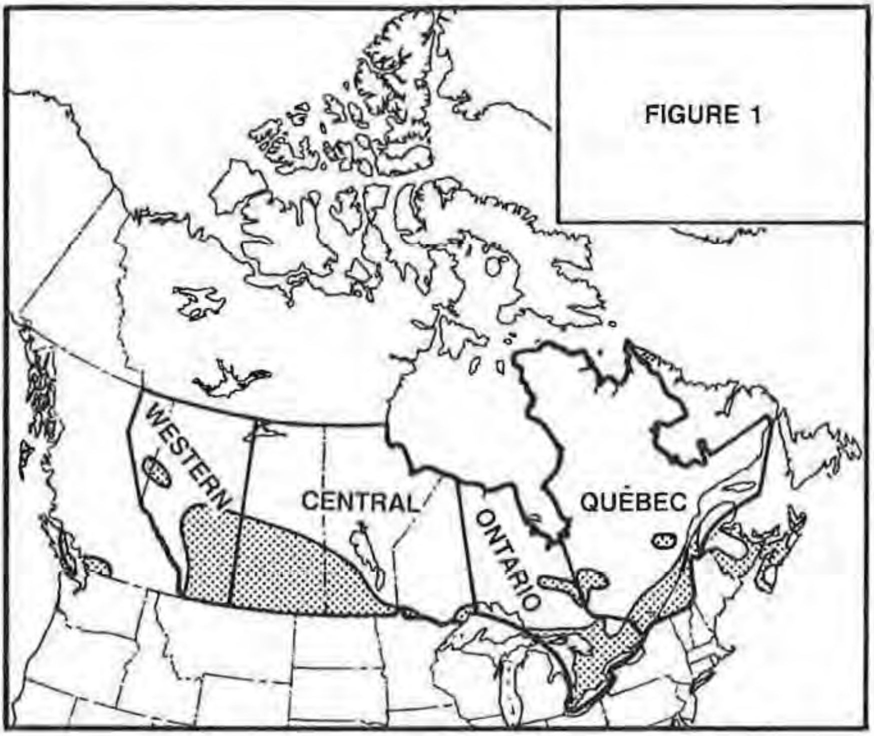

FIGURE 1   Regions making a seasonal severe local storm report. Areas of population density > 1 per km² are shown approximately by shading.

a distinct event. These have been referred to as "proper-events" (Legal, 1984). In practice, difficulties arise when this is attempted because often there is not enough information available to distinguish each unique event. Even when there is sufficient information, it is not always possible to determine whether a series of damage incidents very closely related in time and space was the result of one intermittent storm, or a succession of independent storms.

The Québec region circumvents this problem by recording severe local storms in terms of "region-events" (Siok, 1984). According to this scheme, weather occurrences which take place within a given forecast region are counted as one region-event provided they occur within an hour or so of each other. The remaining regions attempt to record proper-events. With resources that vary from year to year, and from region to region, and without a clear definition of what constitutes a proper-event, the numbers of events shown in Table 2 should be treated with great caution because it is not known how well they represent the true numbers. The number of tornadoes is perhaps an exception because a greater effort is expended on collecting information about them and identifying each one.

TABLE 2. Severe Local Storm Summary for 1984

AES REGION	WESTERN		CENTRAL			ONTARIO	QUÉBEC		NATIONAL
PROVINCE	NERN BC	ALTA	SASK	MAN	NWRN ONT	ONT	SERN ONT	QUÉ	
SEVERE LOCAL STORMS[a]									
Number of events	M		57	70	12	70	M		M
Number of days	41		21	17	6	27	29		81
Number of deaths	2		0	0	1	0	1		4
Number of injuries	2		0	5	0	0	38		45
Date season started	Apr 27		May 12			May 22	May 12		Apr 27
Date season ended	Sep 1		Aug 19			Sep 25	Oct 3		Oct 3
Length of season (days)	128		100			127	138		160
TORNADOES									
Number of events	15		16	17	5	21	M		M
Number of days	9		6	6	4	10	1 / 2		31
Number of deaths	1		0	0	0	0	1		2
Number of injuries	1		0	5	0	0	38		44
Date season started	Apr 27		May 12			May 22	Jun 7		Apr 27
Date season ended	Aug 9		Aug 8			Sep 10	Oct 3		Oct 3
Length of season (days)	105		89			112	119		160
HAIL									
Number of events	M		11	29	2	18	M		M
Number of days	29		9	13	2	10	11		50
Date season started	Jun 12		May 12			May 22	May 12		May 12
Date season ended	Sep 1		Aug 19			Sep 2	Sep 1		Sep 2
Length of season (days)	82		100			104	113		114
WIND									
Number of events	M		16	10	5	22	M		M
Number of days	11		10	7	3	19	13		48
RAIN									
Number of events	M		12	10	0	9	M		M
Number of days	8		7	9	0	6	18		37
WATERSPOUTS									
Number of events	1		0	7	0	1	M		M
FUNNEL CLOUDS									
Number of events	16		19	18	6	14	M		M
LIGHTNING									
Number of deaths	M		0	2	0	2	1		M

M = Not known

Some statistics in the "National" column are not truly representative due to regional differences in definition (see Table 1).

a = Not including waterspouts or funnel clouds.

3. DATA SOURCES

Reports of severe local storms in 1984 were gathered as follows: (a) from the primary observing network of AES; (b) from volunteer weather watchers in each region; (c) from newspaper clippings; (d) from field surveys of storm damage (for example, Voak et. al., 1984; Bertolone, 1985); (e) from contacts with the media, private individuals, provincial agencies, insurance companies etc.; (f) from the Environment 2000 mesoscale project in Manitoba (Legal, 1984). More detailed information concerning sources can be found in the individual regional reports (Letchford et al., 1984; Legal, 1984; Leduc, 1984; and Siok, 1984). It should be noted that the information is gathered primarily from populated areas (approximately shown by the shaded areas in Figure 1).

4. SEASONAL HIGHLIGHTS

4.1 *"National"*

Severe local storms (as defined in Table 1) occurred on 81 days during a season which began on April 27th, ended on October 3rd, and lasted 160 days. The storms were responsible for at least 4 deaths and 45 injuries. In addition, at least another 5 people were killed by lightning. Perhaps the most notable outbreak of severe local storms occurred on June 29th, when a number of tornadoes, hailstorms and thunderstorms producing damaging winds crossed northern Alberta while others lashed southwestern Saskatchewan. During this season there were 48 days with severe wind storms and 37 days with severe rain storms.

The tornado season was coincident with the severe local storm season and produced a minimum of 77 tornadoes on 31 days. They were responsible for 2 of the deaths and 44 of the injuries.

Severe hail occurred on 50 days during a season which began on May 12th, ended on September 2nd, and lasted 114 days.

Waterspouts and funnel clouds were considered to be severe local storms in some regions in 1984. There was a total of at least 9 waterspouts reported and at least 67 funnel clouds.

A summary of these statistics is provided in Table 2. Tables 3 to 7 show the days when the various types of storms occurred in the four regions.

4.2 *The Western Region (northeastern B.C. and Alberta)*

A comparison of the last three convective seasons from 1982 to 1984 would, at first glance, imply a trend toward more severe weather days, with the increase not attributable to any particular type of event. Consider however, that the weather watcher network was operative during the 1984 season and responded with many reports of severe weather that otherwise would not have been detected. It may then be stated that, absolute numbers aside, the 1984 severe weather season likely had fewer events than 1983.

Reported tornadic activity has decreased the past two seasons when compared to the very active season of 1982. Nonetheless the 15 tornadoes of 1984 were nearly triple the long term average of 5.5 (Newark, 1983). Of the 15 tornadoes, 7 occurred during the outbreak of June 29th north of Athabasca. Hence, when the number of tornado days is examined, the 6 tornado days in 1984 are only slightly more than the average of 3.9. It is certain that some tornadoes go undetected or unreported due to the low population density. It is our hope that continued media exposure of severe weather, together with the weather watch network, will improve the detection of severe events.

An interesting statistic shows that severe weather has been reported on one day in three for the last two summers. It is suspected that a better

TABLE 3. Severe Local Storm Days, 1984

1 – NERN BC; 2 – ALTA; 3 – SASK; 4 – MAN; 5 – NWRN ONT; 6 – ONT; 7 – SERN ONT; 8 – QUE; 9 – NATIONAL

	1 2	3	4	5	6	7 8	9
Apr 27	*						
28	*						
May 12		*				*	
16		*					
18	*						
20		*					
22					*		
23	*				*	*	
25						*	
29						*	
30			*				
Jun 6		*	*		*		
7	*					*	
9					*		
12	*	*					
13	*				*		
15	*	*	*				
16		*	*				
18					*	*	
19	*					*	
20		*					
21			*				
22		*	*				
23					*		
24					*	*	
25	*	*					
27					*		
29	*	*					
Jul 4	*						
5	*						
6	*	*			*	*	
Jul 8			*	*	*		
9	*	*					
10			*				
11	*				*	*	
12	*		*			*	
13			*	*			
14				*		*	
15					*	*	
16	*		*			*	
17	*				*		
18	*						
19	*						
20		*	*		*	*	
21	*		*		*	*	
23						*	
27	*						
28	*						
29		*					
30	*						
31		*	*				
Aug 2	*			*	*		
3	*					*	
4		*					
5	*	*	*			*	
6	*					*	
8			*	*			
9	*						
10					*	*	
11	*				*		
12	*						
13	*						
Aug 14					*		
15						*	
17	*						
18	*	*			*		
19	*	*	*				
22	*				*		
23	*					*	
24	*						
25	*						
26				*			
29		*			*	*	
30					*	*	
Sep 1	*					*	
2					*		
10					*		
20						*	
25					*		
26						*	
Oct 3						*	
TOTAL	41	21	17	6	27	29	81

information gathering system is responsible for the higher number reported during the past two years, rather than an increase in severe thunderstorm activity. There were more severe events in August 1984 than in July, a month that is usually more climatologically favoured. This may be attributed to the lack of thunderstorm activity in southern Alberta due to drought during July of 1984.

An historic severe weather day for Alberta occurred June 29th when a complex of severe storms originated south of Drayton Valley and tracked northeastward to Fort McMurray, a distance of nearly 500 kilometres. Along the path of the storms at least five tornadoes were spawned, hail larger than golfballs was reported, and wind gusts were measured at 100 kilometres per hour. Two fatalities and several injuries were caused by the storm. Property damage alone exceeded one million dollars. On the same day a second line of severe thunderstorms developed in eastern Alberta. Two tornadoes and wind

TABLE 4. Tornado Days, 1984
1 – NERN BC; 2 – ALTA; 3 – SASK;
4 – MAN; 5 – NWRN ONT; 6 – ONT;
7 – SERN ONT; 8 – QUE;
9 – NATIONAL

	1 2	3	4	5	6	7 8	9
Apr 27	*						
28	*						
May 12		*					
16		*					
18	*						
20		*					
22					*		
Jun 7	*					*	
12		*					
13	*				*		
16		*	*				
18					*		
21			*				
22			*				
29	*	*					
Jul 6					*		
8			*	*			
12			*				
13				*			
14				*			
15						*	
21	*						
Aug 2	*			*	*		
8			*				
9	*						
11					*		
14					*		
30					*		
Sep 2					*		
10					*		
Oct 3						*	
TOTAL	**9**	**6**	**6**	**4**	**10**	**3**	**31**

TABLE 5. Severe Hail Days, 1984

1 – NERN BC; 2 – ALTA; 3 – SASK; 4 – MAN; 5 – NWRN ONT; 6 – ONT; 7 – SERN ONT; 8 – QUE; 9 – NATIONAL

		1 2	3	4	5	6	7 8
May	12		*				*
	16		*				
	22					*	
	23					*	
Jun	6					*	
	12	*					
	13					*	
	15			*			
	18					*	
	19	*					
	21			*			
	22		*	*			
	25	*	*				
	29	*					
Jul	4	*					
	5	*					
	6	*	*				
	8			*			
	10			*			
	11	*					*
	12	*		*			*
	13			*	*		
	14				*		
	15						*
	16	*		*			*
	17	*				*	
	19	*					
	20			*			*
	21	*		*		*	*
	27	*					
	28	*					

		1 2	3	4	5	6	7 8	9
Jul	30	*						
	31		*	*				
Aug	2	*						
	3	*					*	
	4		*					
	5	*	*	*			*	
	6	*						
	11	*						
	13	*						
	14					*		
	15						*	
	17	*						
	18	*				*		
	19	*	*	*				
	22	*						
	24	*						
	25	*						
Sep	1	*					*	
	2					*		
TOTAL		29	9	13	2	10	11	50

1980, there were only 34 severe weather days in 1984. Note that this number does not agree with the total obtained from Table 2 due to the overlap of some days from one province to another within the Region.

The season started with the Whitewood, Saskatchewan tornado on May 12th. Other dramatic severe weather events include the flooding in the Winnipeg area in mid-June, the July 8th St. Claude-Rosenort tornado, the family of waterspouts over Lake Winnipeg on August 8th and the Prince Albert wind storm of August 19th.

Two men were killed by lightning, one in Winnipeg on June 21st and another near Roland, Manitoba on July 12th. A third death was caused indirectly by lightning near Lockport, Manitoba on October 11th. The only fatality due to severe storms was a passenger in a car which was blown off the road north of Thunder Bay on August 8th.

TABLE 6. Days with Severe Local Wind, 1984
1 – NERN BC; 2 – ALTA; 3 – SASK; 4 – MAN; 5 – NWRN ONT; 6 – ONT; 7 – SERN ONT; 8 – QUE; 9 – NATIONAL

	1 2	3	4	5	6	7 8	9
May 12		*					
16		*					
23	*						
30			*				
Jun 6					*		
9					*		
13					*		
16			*				
19	*					*	
23					*		
24					*		
25	*						
27					*		
29	*	*					
Jul 6		*			*	*	
8			*		*		
9	*	*					
11					*		
12						*	
13			*				
14				*			
15					*	*	
16						*	
18	*						
20		*			*		
21			*			*	
23						*	
28	*						
29		*					
Aug 3						*	
5			*			*	
Aug 8				*			
10					*		
12	*						
15						*	
18		*			*		
19	*	*	*				
22					*		
23	*						
24	*						
26				*			
29		*			*		
30					*	*	
Sep 2					*		
10					*		
20						*	
25					*		
26						*	
TOTAL	11	10	7	3	19	13	48

4.4 *The Ontario Region (excluding northwestern and extreme southeastern section of Ontario)*

Although reports of severe weather were down noticeably from 1983, the summer of 1984 was still above normal and will be particularly memorable in certain portions of the province. The first severe weather of note was on May 22nd when two tornadoes were reported in central Ontario. The last significant storm day was September 10th when three tornadoes occurred just south and southeast of Lake Simcoe. August and early September was the most active period when severe weather was reported on 10 days between August 8th and September 2nd.

The area around London was particularly hard hit in 1984 with severe weather being reported on no less than ten days. The most notable event occurred on September 2nd when a major tornado did in excess of five million

TABLE 7. Days with Heavy Local Rain, 1984
1 – NERN BC; 2 – ALTA; 3 – SASK; 4 – MAN; 5 – NWRN ONT;
6 – ONT; 7 – SERN ONT; 8 – QUE; 9 – NATIONAL

	1 2	3	4	5	6	7 8	9
May 12		*					
23						*	
25						*	
29						*	
Jun 6		*	*		*		
13					*		
15	*	*	*				
16			*				
18					*	*	
19						*	
20		*					
21			*				
22		*	*				
24						*	
Jul 6						*	
8			*				
11						*	
12	*		*				
13			*				
14						*	
15						*	
16						*	
20					*	*	
28	*						
29		*					
31		*					
Aug 2	*						
5	*		*				
6	*					*	
10						*	
15						*	
Aug 18					*		
19	*						
23						*	
24	*						
29					*	*	
30						*	
TOTAL	**8**	**7**	**9**	**0**	**6**	**18**	**37**

dollars damage to the south part of the city (Bertolone, 1985). September 2nd also saw hail up to the size of baseballs and several other small tornadoes to the west and northwest of London. Hail, damaging winds or flooding rains were also reported in the London area on three days in each of the months of June, July and August.

The Hamilton area experienced a stormy period in mid June. Severe thunderstorms on June 13th and June 18th caused two lightning deaths and major damage due to flooding.

A tornado struck the north part of Toronto on August 14th causing millions of dollars damage. This storm was very unusual in that it moved from the northeast to the southwest, an almost unheard-of event in tornado statistics.

There were a few other storms of note. The Westport tornado on

June 18th (Voak et. al., 1984) severely damaged a small group of buildings just outside that eastern Ontario town. On July 6th several tornadoes were reported across southwestern and central Ontario. The most noteworthy of these storms badly damaged a townhouse unit in Elora.

4.5 *The Québec Region (southeastern Ontario, Québec)*

Confirmed severe storms occurred on 29 days during the 1984 season which began on May 12th, and ended on October 3rd. Flooding downpours were particularly common. In the second half of August some regions such as Pontiac, Gatineau and Laurentian were inundated four times within two weeks by rainfalls in the 50 to 100 mm range. The Pontiac and Gatineau regions were also struck by tornadoes on July 15th when cottages were flattened, other buildings damaged and at least 38 people injured by flying debris (Allen, 1984). At Blue Sea Lake, a woman was killed. On August 3rd, another fatality was suffered when lightning struck and killed an individual at Granby. Other dramatic events include May 23rd when severe thunderstorms caused considerable damage near Rivière-du-Loup, June 18th when parts of Montreal were flooded, and July 6th when damaging winds, large hail and flooding downpours ravaged parts of the Eastern Townships, near Sherbrooke.

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News and Comments
Nouvelles et commentaires

ALBERTA CLIMATOLOGICAL ASSOCIATION ANNUAL MEETING

The 11th Annual Meeting of the ACA is scheduled for February 24, 1987. This year, the meeting will be held at the Northern Forest Research Centre in Edmonton. The theme of the technical session will be Current Activities in Applied Climatology.

CLIMATE CHANGE INFORMATION

Henry Hengeveld
CO_2/Climate Advisor
Canadian Climate Centre

Climate change, and man's possible role as a perpetrator of such change, has been a major scientific concern within the international research community for more than a decade. It still is today! Related research to remove the large uncertainties that still remain and to better define its implications for society are by necessity resulting in unprecedented levels of cooperation and interaction between the various disciplines of the physical sciences, particularly at their interfaces. The Canadian research community continues to be an active participant in this research.

Several years ago, in order to stay abreast of developments in the above international research and to keep Canadian decision makers advised, the Canadian Climate Centre of the Atmospheric Environment Service initiated an advisory service on changing atmospheric chemical composition and climate. Financially assisted by the national Energy Research and Development program (administered by the federal Department of Energy, Mines and Resources), this service attempts to assimilate recent results of related research activities and transfer this information to the broader Canadian scientific and policy-making communities and to the general

Canadian public through newsletters, annual reports, consultations and briefings. One of the information products issued as part of this program is a periodic (3-4 times/year) newsletter, the "CO_2/Climate Report," which attempts to update readers on recent developments in related research activities and results. In addition an annual report entitled "Understanding CO_2 and Climate," which tries to summarize the current status of understanding of this subject within the international scientific community, is released in the spring or early summer of each year.

Readers can arrange to be included on the mailing list for the above reports, which are disseminated free-of-charge, by contacting the CO_2/ Climate Advisor, Mr. Henry Hengeveld, at the Canadian Climate Centre, 4905 Dufferin Street, Downsview, Ontario, M3H 5T4. Mr. Hengeveld is also available for consultation and as a source for additional information. He can be reached at (416) 667-4525.

SASKATCHEWAN CLIMATE ADVISORY COMMITTEE

Ken Jones
Secretary
Saskatchewan Climate Advisory Committee

The SCAC held its third annual workshop in October 1986. The workshop took place in the new confines of the National Hydrological Research Centre in Saskatoon. The general theme of the workshop was "Computer Applications of Climate data." Ten presentations were made covering a wide range of applications, varying from how to access the AS-9 in the Canadian Climate Centre to modelling snow drifting and melt. A tour of the new NHRC facilities followed the workshop.

Another major activity of the SCAC this year involved the initializing of a study regarding "The Feasibility of a Saskatchewan Climate Centre." Progress has been slow but the funds have now been acquired to proceed with this study.

ACFAS ANNUAL CONFERENCE

The 54th conference of the "Association Canadienne Française pour l'Avancement des Sciences" (ACFAS) will be held on 19-22 May, 1987, at the University of Ottawa. The main theme of the meteorology and climatology sessions will be "The Impact of Climatic Change." Roger Barry (Colorado and NCAR) will give a presentation on "Impacts of Climate Change on Snow and Ice Conditions in the Arctic."

Other sessions will include papers on air pollution, physical and dynamic meteorology/climatology, statistical climatology, agroclimatology, paleoclimatology, urban climatology, and remote sensing applications. Simultaneous translation will be provided.

The deadline date for abstracts was 15 January 1987. For more information, contact:

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