Chinook

THE CANADIAN MAGAZINE OF WEATHER AND OCEANS
LA REVUE CANADIENNE DE LA MÉTÉO ET DES OCÉANS

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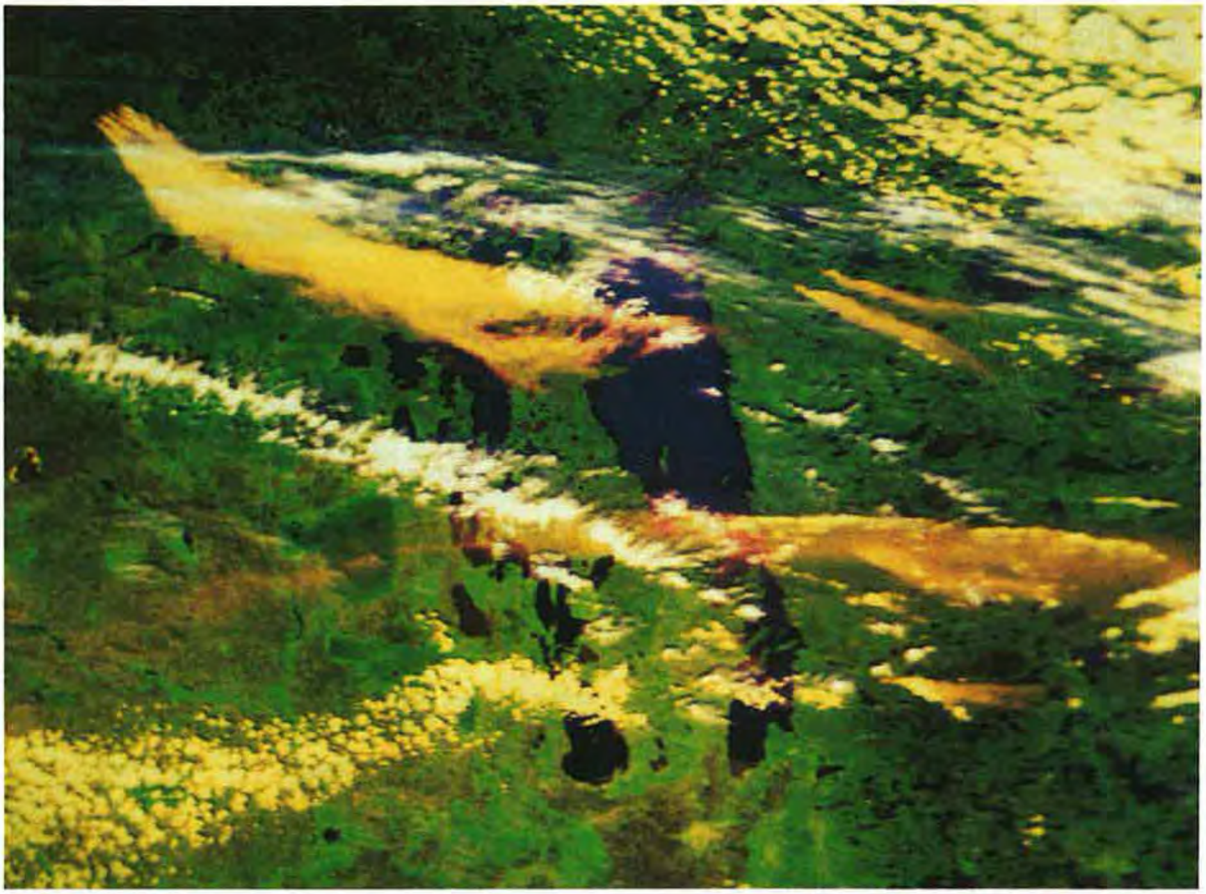

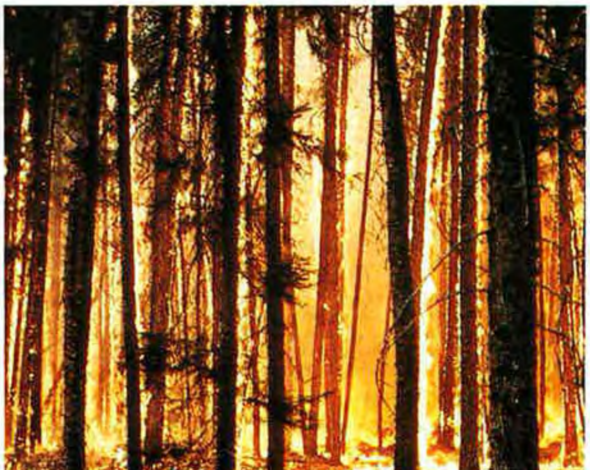

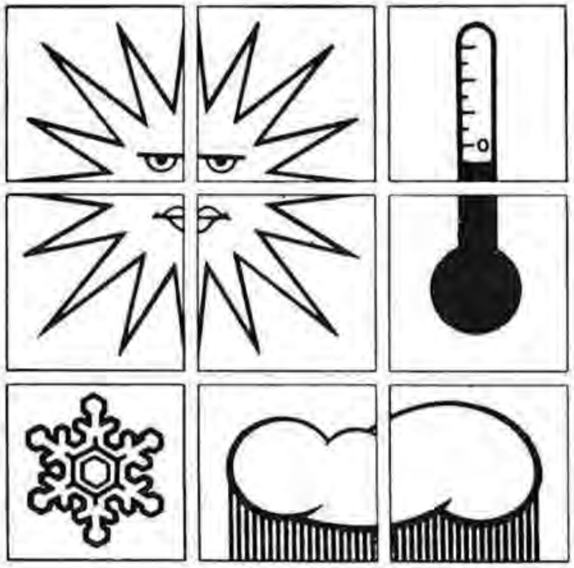

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Canada

FROM THE EDITOR'S DESK

A new year has started and with that a new volume of *Chinook,* which is also the tenth volume of our publication. Thanks to Mike Newark who had the foresight and energy to recognize the need in Canada for a popular magazine dealing with the weather and oceans.

Looking back over the first six years, we must note the tremendous amount of effort that Mike gave to his favourite project. We thank him for keeping the dream alive – under difficult circumstances – and for allowing the Society to carry on with *Chinook* from 1984 to the present.

I know that I speak on behalf of the Society, the Board members, and more specifically on behalf of the editorial team, in expressing satisfaction with our progress to date. It has not been easy, but it has been most satisfying.

In this issue we are offering some insights into two of the most destructive forces in nature: forest fires and tornadoes. Forest fires consume millions of dollars of valuable timber in the vast forest regions extending from the Pacific to the Atlantic coast. Tornadoes often strike with little warning. We offer you a view from the forcaster's desk of the horrible 90 minutes that occurred in Edmonton on July 31, 1987.

At the Editor's desk we would very much like to hear from you. We look forward to your comments and contributions.

Hans VanLeeuwen

LETTERS

The Dutch Armada of 1688

I have read with interest and pleasure the paper "Flavit et Dissipati Sunt ..." by H.H. Lamb and C. Loader, published in the Spring 1987 issue of your journal.

In 1988 will be the 400th Anniversary of the attempted attack on England by the Spanish Armada. But there will be another important Anniversary in the same year: The 300th Anniversary of the "descent" on England by the Prince of Orange – the future William III.

I attach herewith a copy of a paper* joint with S. Lindgrén on the meteorological aspects of the "descent" and the historical situation in England that brought the Prince of Orange over to England.

J. Neumann
Department of Meteorology
Copenhagen University

*Great Historical Events That Were Significantly Affected by the Weather: 7, "Protestant Wind"— "Popish Wind": The Revolution of 1688 in England. *Bulletin of the American Meteorological Society,* Vol. 66, 634–644 (1985).

Chinook

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COVERS

Details about the front and back covers illustrating two of the atmosphere's most devastating phenomena and their impacts are given in the articles on forest fire meteorology and the Edmonton tornado.

COUVERTURES

Les pages couvertures illustrent deux des phénomènes atmosphériques les plus dévastateurs; des détails sur ces phénomènes sont présentés dans l'article sur la météorologie et les incendies de forêt, et celui sur la tornade d'Edmonton.

FOREST FIRE METEOROLOGY

by Roger B. Street

Fire is a natural recurring phenomenon within Canada's forested areas. Our boreal forest regions in particular are dominated by tracts of even-age stands that attest to the relationships between our forests and fire. An analysis of the losses associated with forest fires during the period 1970–1985 (see Table 1) yields the relative frequencies of fires in Canada.

The inception, growth and behaviour of forest fires are closely linked to meteorological and climatic phenomena, forest fuels and topographic features. This complex has been labelled "the fire environment". A close relationship exists between the various factors of the fire environment, whose spatial and temporal variations occur in a dynamic and integrated fashion. However, the atmosphere plays the dominant role. This is reflected by its incorporation into all phases of forest fire management: presuppression, preparedness, prevention, suppression, prescribed burning, and natural fires. Information on the past, present and future states of the atmosphere is (or should be) an integral part of all fire management activities. This is due to the natural links that exist between weather and forest fires, including the exchange of water between the atmosphere and the forest fuels, ignition, and the combustion and the propagation processes.

In fire management there is a distinct advantage to be gained from being able to anticipate, well in advance, the forest fire hazard and the probable behaviour of burning fires. This capability is met, in part by meteorological information systems, by fire weather forecasts, and by the operation of the Canadian Forest Fire Danger Rating system (Charles Van Wagner, 1974). Recognition of the warning signs of a potentially dangerous situation, or of conditions that would not allow a particular fire management strategy to meet its objective, is necessary so that fire management plans can be successful.

The weather conditions that are conducive to rapid fire spread are strong winds, low relative humidities, high temperatures, and deficient rainfall. These critical fire weather conditions are normally associated with particular surface weather systems and upper-air patterns. If periods of critical fire weather can be recognized and monitored by means of their relationships with synoptic weather patterns, preparations can be made to counter a possible disaster and to reduce the amount of damage.

Table 1 Forest fire statistics for Canada (Gordon S. Ramsey and Douglas G. Higgins, 1986).

Year	Number of Fires	Area Burned (hectares)
1985	9,357	757,260
1984	9,568	765,382
1983	8,930	1,194,175
1982	8,941	1,697,591
1981	10,145	5,413,365
1980	8,973	4,822,167
1979	9,793	2,700,785
1978	7,928	289,417
1977	8,888	1,483,194
1976	10,161	1,813,825
1975	10,995	1,032,034
1974	8,035	848,674
1973	7,503	1,184,283
1972	8,153	780,037
1971	9,125	1,695,013
1970	9,253	1,058,843

Certain characteristics of the upper-air flow are closely related to periods of critical fire weather. Those upper-air features that divert (or block) the flow of moisture or cooler air or both away from a particular area may pose a threat to that area's fire weather.

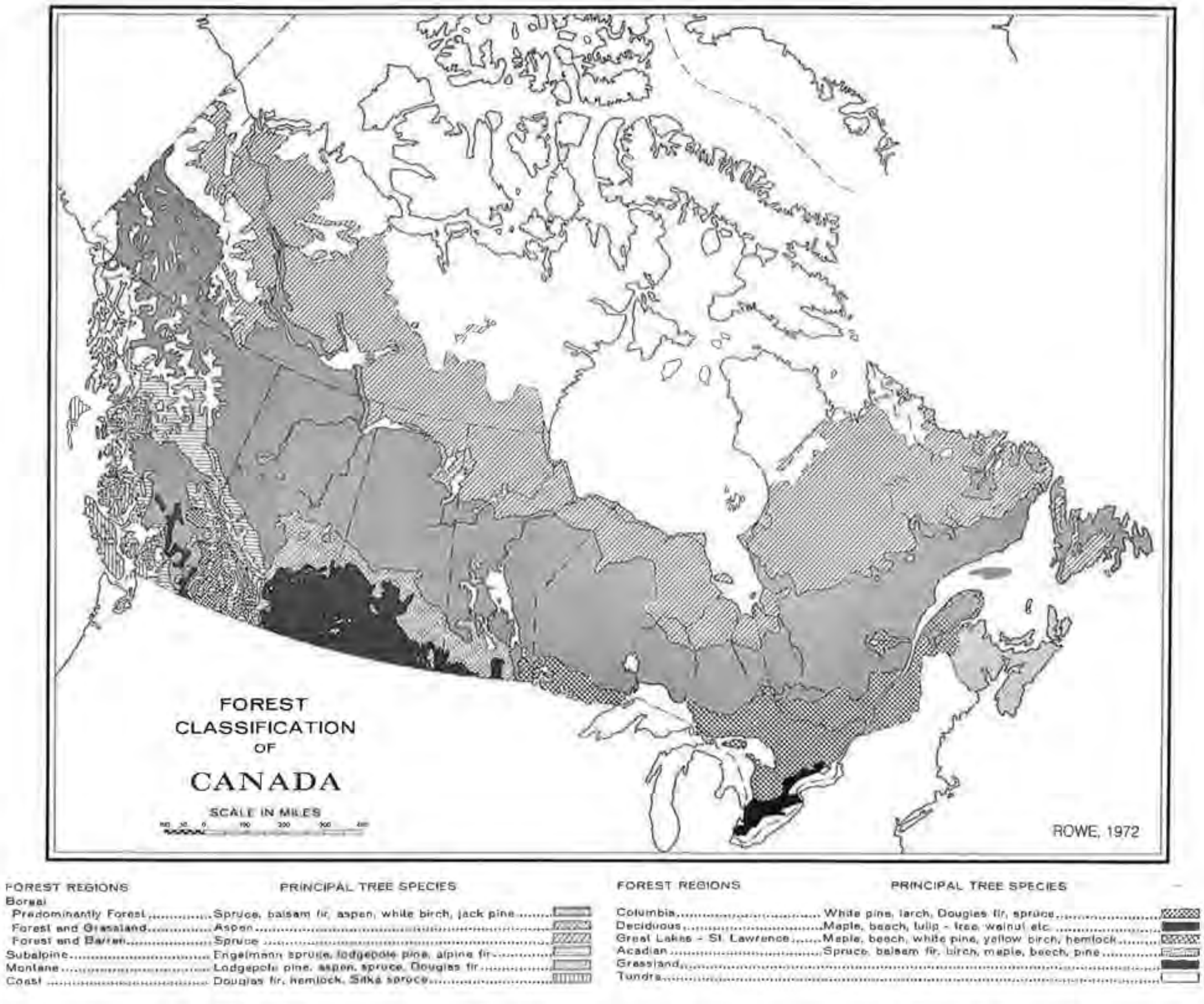
A comparison between monthly fire statistics for 1953–1980 as compiled by James Harrington in 1982 and corresponding weather features shows a relationship between the areas burned and specific weather patterns. This analysis revealed that during the months when the area burned in northwestern Ontario was significantly greater than the average a prominent weather feature was situated over the Prairie Provinces and/or over northwestern Ontario, which prevented the influx of atmospheric moisture into northwestern Ontario. In addition, this type of weather pattern sustained a flow of warm, dry air at the surface into northwestern Ontario from the south-central United States, which in turn heightened the probability of a severe forest fire.

Particular weather features are synonymous with severe fire weather. George Byram in a 1954 study of atmospheric conditions that accompanied a number of extreme fire events determined that fires seem most likely to blow up when the following conditions exist simultaneously:

- Fuels are dry and plentiful.
- The atmosphere either is unstable or was unstable for some hours and possibly days prior to the fire.
- The wind speed is 29 km/h or more at an elevation equal to or not much higher than the elevation of the fire.
- The wind speed decreases with height for several thousand metres above the fire with the possible exception of the first hundred metres.

Byram's analysis revealed numerous cases of explosive fire behaviour that were associated with wind speeds decreasing with height and on this basis he suggested a rather simple classification of wind profiles that were related to fire behaviour. The most dangerous types had winds in excess of 29 km/h at or just above the fire, and a marked decrease of wind with height above this layer. In a detailed analysis in 1964 of weather features associated with criti-

A Canadair CL-215 water bomber attacking a northern Ontario fire.



cal fire weather in the United States George Schroeder and others of the U.S. Forest Service found that the highest fire potential occurred in the peripheries of high-pressure areas in the vicinity of dry, cold fronts.

By examining a number of fire histories, Edward Brotak and William Reifsnyder in a 1976 study showed that the weather patterns associated with major fires were similar to those that usually produce precipitation and poor fire conditions. The reason for the lack of precipitation just before and during an extreme fire weather situation appeared to be a deficiency of moisture in the air over the affected area. They examined moisture advection (i.e., the horizontal moisture transport into an area) at low levels of the atmosphere (85 kPa) and found that in the vast majority (93%) of the fires, lack of low-level moisture advection was the major factor contributing to the development of large fires.

Moisture advection depends primarily on wind flow patterns and moisture sources. For areas in eastern and central North America the major sources of moisture are the Gulf of Mexico and the Atlantic Ocean. The lack of moisture advection at low levels for most of the fire runs studied by Brotak and Reifsnyder was due to a zonal flow pattern over the area of the fire. Flows with a more southerly or easterly trajectory (i.e., from the moisture sources) were found to be unfavourable for fire runs. In the western part of the continent, a zonal flow would be unfavourable for fire runs since the air would flow from a moisture source (Pacific Ocean and/or Gulf of Alaska). However, a flow pattern that was strongly meridional would normally result in poor moisture advection, i.e., favourable for fire runs, over western Canada.

The surface weather features normally associated with a critical fire weather situation are the dry, cold front and the high-pressure area, in particular its peripheries. These features are favourable for major fire runs (rapidly spreading fires) because they are the areas where high wind speed and turbulence, low relative humidities and lack of rainfall can be found. Edward Brotak and William Reifsnyder in their 1976 survey of 52 major wildland fires found that "...more than half of all fire runs occurred following the passage of a dry, cold front ... with most runs occurring in the southeastern section of the frontal region" (Figure 1). They concluded that this is the primary area in which the proper combination of wind speed, moisture, temperature and fuel conditions are found. According to these investigators, "One quarter of the runs occurred prior to the passage of a cold front. Often, fires would make a run both ahead of and behind the front. Thus, three quarters of the fire runs were frontal situations".

About 12% of the fire runs examined by Brotak and Reifsnyder occurred in the warm sectors of low-pressure areas, while 5% were associated with high-pressure areas situated far from any fronts or low-pressure areas. Usually, these high-pressure areas originated in low latitudes and had very high temperatures and extremely low relative humidities. Four fire runs (5%) occurred

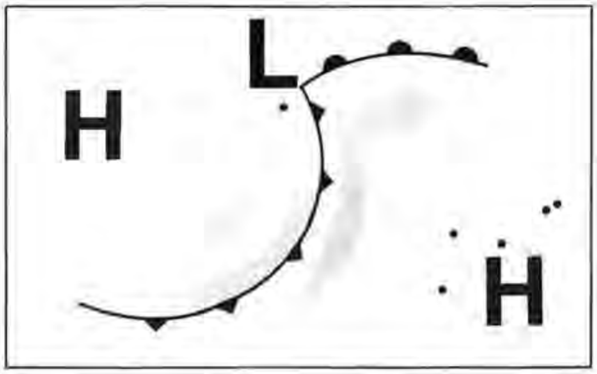


Figure 1 Idealized surface weather map showing preferred areas (shaded) and locations (dots) of major fire runs (Brotak and Reifsnyder, 1976).

with other than a dry, cold front or high-pressure area as their dominant surface weather feature.

As outlined by George Byram, an unstable or recently unstable atmosphere is one of the conditions normally associated with severe fire weather. This relationship is mainly due to the turbulent winds usually associated with atmospheric instability, which can cause forest fires to build up very rapidly and to behave erratically. However, the existence of a stable layer near the ground can also produce hazardous fire weather. Two phenomena that can result in some of the most dramatic effects of stability on fire behaviour are the nocturnal and subsidence inversions. Fires burning within stable air are usually slow moving and easily controlled, however, they are potentially dangerous. When the inversion (stable layer) is shallow, it may dissipate quickly by convection from below induced by the sun's radiation or the fire itself. Once the inversion is broken down, the turbulent energy that was isolated above the inversion is released and is suddenly made availabe to the fire. Explosive increases in the aggressiveness and rate of spread of fires are at times ascribed to this mechanism.

Associated with surface high-pressure systems and their divergent flow is a sinking of the overlying atmosphere. This sinking from aloft is the common form of subsidence. Because of its origin, subsiding air in the upper troposphere is usually very dry (relative humidities typically 2–5%) and warm. If this air reaches the surface the effect on fuel moisture and fire behaviour is dramatic, resulting in a potentially critical fire weather situation.

Subsiding air seldom reaches the surface as a broad layer, but more often sinks to the lower troposphere and stops. Some transport mechanism is then required to bring this dry, subsiding air down to the surface: one effective means is the convection current associated with daytime heating. The upward moving air and the compensating downward currents transport the dry air downward, causing it to mix with the air in the layer below the subsidence inversion. Although the resulting air is not as dry as the pure subsiding air, it still has a very low relative humidity and remains quite warm.

The relation between fire behaviour and the weather that precedes and occurs during a fire can be illustrated by examining in detail a fire that occurred in the Fort Frances, Ontario, area during 1981. A major weather system situated over the Prairie Provinces dominated the northwestern Ontario weather in the weeks preceding the ignition date. This system directed warm, dry air into the area and was instrumental in the earlier than normal spring snowmelt throughout northwestern Ontario. Both Kenora and Fort Frances reported no snow on the ground at the end of March. Precipitation was well below normal at Kenora during the months of April and May (32% and 13% of normal, respectively), while mean daily temperatures and hours of bright sunshine were well above their seasonal normals. This combination of meteorological factors and the resulting fuel mixture created a fire climate in the Fort Frances area in late May that would support extremely fast fire growth and spread.

The fire was detected on May 20, 1981, burning in logging slash about 45 km north-northeast of Fort Frances. On May 20 and 21, 1981 (Figure 2) a surface low-pressure system over southwestern Canada strengthened and moved slowly eastward across the Northern Plains of the United States. At the same time, a surface high-pressure system encompassing the Great Lakes remained almost stationary. This relative positioning of weather systems was responsible for the fire escaping the initial firefighting efforts or "attack" by firefighting crews and its growing to about 900 hectares, mainly in cutover, by the evening of May 20. The motion of the western low-pressure centre relative to the Great Lakes high-pressure cell produced a tightening of the surface pressure gradient and a strengthening of the winds over the area between the two systems. In addition, the east-west air temperature gradient in the lower layers over the central United States, set up by surface heating of the air over

FRONT COVER

The upper illustration is a satellite image as received from the U.S. NOAA-9 satellite at 2143 GMT on May 8, 1987. The image is shown in false colours indicating the various terrain, vegetation, cloud, and smoke regimes. Lakes Winnipeg and Manitoba are clearly delineated, as well as the urban sprawl of Winnipeg (southwest of the southern tip of Lake Winnipeg). The most striking features are the forest fires over central Saskatchewan (upper left corner) and central Manitoba, the two fires east of the northern part of Lake Winnipeg, and the one farther south on the Ontario-Manitoba border. The image presents a dramatic view of the long plumes of smoke that are carried eastward with the west-northwesterly upper flow in the atmosphere. (Photo credit: AES Satellite Laboratory, Downsview, Ontario).

The lower pictures show destructive flames shooting high in the sky consuming valuable timber in a fire at Red Lake, Ontario, and an internal view of the forest inferno (Photos: Brian J. Stocks).

COUVERTURE AVANT

Image supérieure. Photo reçue du satellite américain NOAA-9 à 2143 TMG, le 8 mai 1987. Les fausses couleurs indiquent les diverses configurations du terrain, de la végétation, des nuages et de la fumée. Les lacs Winnipeg et Manitoba sont parfaitement visibles, de même que la ville de Winnipeg (au sud-ouest de l'extrémité sud du lac Winnipeg). Les aspects les plus remarquables de la photo sont les incendies de forêt sur le centre de la Saskatchewan (coin supérieur gauche), sur le centre du Manitoba, les deux incendies à l'est du secteur nord du lac Winnipeg et, enfin, plus au sud, l'incendie à la frontière Manitoba-Ontario. On peut voir les longues plumes de fumée se déplaçant vers l'est poussées par les courants atmosphériques ouest-nord-ouest. (Photo : Laboratoire de données satellitaires, Downsview, Ontario)

Images inférieures. Flammes dévastatrices jaillissant haut dans le ciel et qui consument des boisés de grande valeur à Red Lake, Ontario. La forêt infernale vue de l'intérieur. (Photos : Brian J. Stocks)

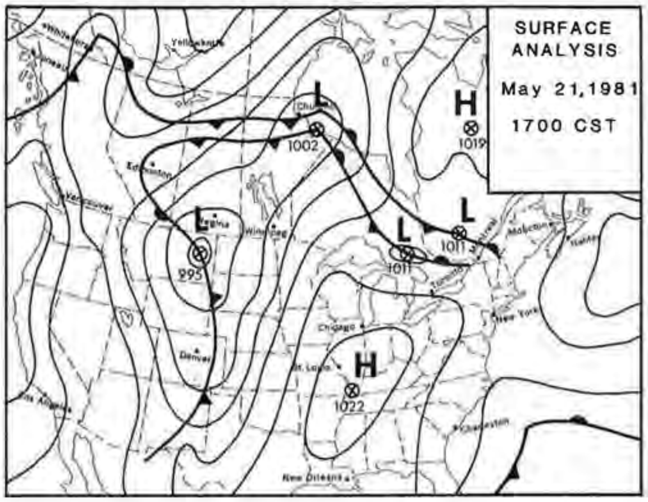


Figure 2 Surface weather map valid for May 21, 1981 at 1700 CST. The location of Fort Frances in Ontario is indicated on the map by a stylized flame.

Figure 3 Photograph of a forest fire burning in northwestern Ontario (Photo: L.G. Huberdeau).

the U.S. Plains, enhanced the southerly flow.

On May 21, driven by gusty southerly winds, this fire ran 22 kilometres in standing timber, reaching a final size of 13,665 hectares. The fire spread at an average rate of 2.4 km/h during the afternoon of May 21, 1981.

The continued eastward progression of the surface low-pressure system spread cloud and widespread precipitation (10.8 mm) into the Fort Frances area on May 22. The precipitation continued on May 23, 24 and 25 and a total of 25.8 mm was recorded at Fort Frances during the three days, ending the fire's spread and allowing suppression crews to bring it under control.

Uncontrolled forest fires (Figure 3) are a reality of life in Canadian forests. The dominant role played by meteorological and climatic phenomena relative to the other factors that make up the fire environment are obvious to those involved in forestry activities, in particular, fire management. This article has explained some of these relationships, however, for a more detailed discussion of this topic, the reader is urged to consult the list of publications that follows.

FURTHER READING

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Roger Street is the Superintendent of the Bioclimate Section of the Canadian Climate Centre and is responsible for applications and climate studies related to forest and agricultural meteorology.

RÉSUMÉ *La fréquence des incendies de forêt au Canada demande des chefs de lutte une compréhension des facteurs qui affectent l'apparition et le comportement de ceux-ci. Les conditions météorologiques jouent un rôle dominant parmi les facteurs (météo, topographie et combustible) qui contrôlent les incendies. Cette étude démontre comment la météo influence les incendies de forêt. Les conditions critiques responsables (vent fort, basse humidité relative, température élevée et manque de pluie) d'une propagation rapide des incendies sont normallement associées à des systèmes météo de surface et des configurations d'altitude caractéristiques. Par exemple, un front froid sec et une zone de haute pression sont favorables au développement d'incendies majeurs; par contre, les configurations de vent transporteur d'humidité provenant des sources océaniques ne le sont pas. L'instabilité atmosphérique est habituellement associée aux propagations les plus importantes. On examine l'historique d'un incendie en fonction des conditions météo associées afin d'illustrer la force du rapport incendie de forêt-conditions météorologiques.*

FORECASTER TELLS EDMONTON TORNADO STORY

by Garry Atchison

The tragic Edmonton tornado of July 31, 1987 was the worst experienced in the city during 97 years of observations. The death toll was 27 and damage was estimated at $250 million.

The last ten days of July 1987 were exceedingly hot and humid in Alberta. Record highs from 31 to 37°C were set at several sites. The dew-point temperatures – a basic measure of humidity, which averages 10°C in an Alberta summer – were reaching the 17 to 21 range during the last week of July. The Alberta Weather Centre had issued severe thunderstorm watches and warnings almost every day for some regions of the province. Subsequent damage reports confirmed the daily development of these storms with damaging winds, large hail, torrential downpours and record levels of lightning.

On Thursday, July 30, two bands of severe thunderstorms developed late in the day and crossed the Edmonton region; the first affected the city and the later one passed to the north during the night. The daily count from the lightning detection system exceeded 40,000 cloud-to-ground strikes, a new record. Arrangements were being made to personally check a report of tornado damage from a weather watcher about 100 km out of Edmonton if Friday's workload would permit.

By Friday morning all watches and warnings had been terminated and skies were practically clear (see weather map, Figure 1). At least one radio announcer scoffed at the 5 a.m. forecast of 80% probability of "thunderstorms at times heavy." After the 7 a.m. shift change, the day shift, which includes the severe weather forecaster, considered the possibility that the worst threat was over since the surface temperatures and dew points were both lower, and the cloud pattern over Saskatchewan suggested that the more dangerous tropical air mass had moved eastward; i.e., that Thursday's action had been related to a weak cold front. However, the usual detailed analysis of the current state of atmospheric stability showed that a good potential for severe thunderstorms remained.

The computer models looked reasonable in pushing a cooling upper trough into southern Alberta late in the day. This development would mean that the high-level jet stream that started the day over eastern British Columbia

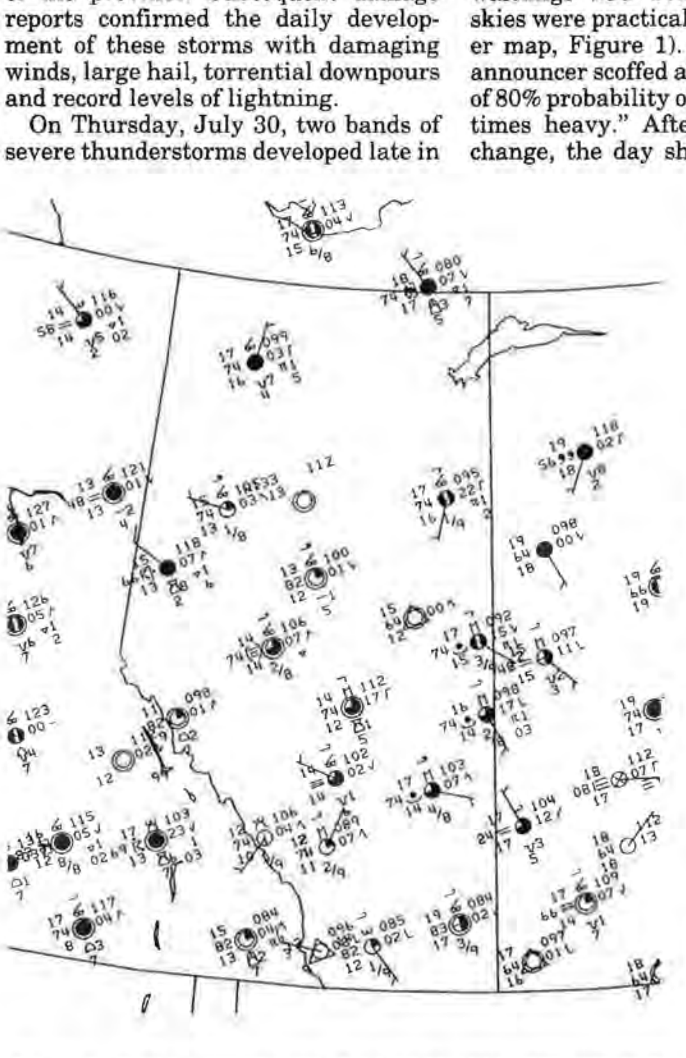


Figure 1 Surface weather plots for July 31, 1987, 1200 GMT (0600 MDT). (To decode the data plotted around each weather station, see *Chinook* Vol. 8 No. 2.)

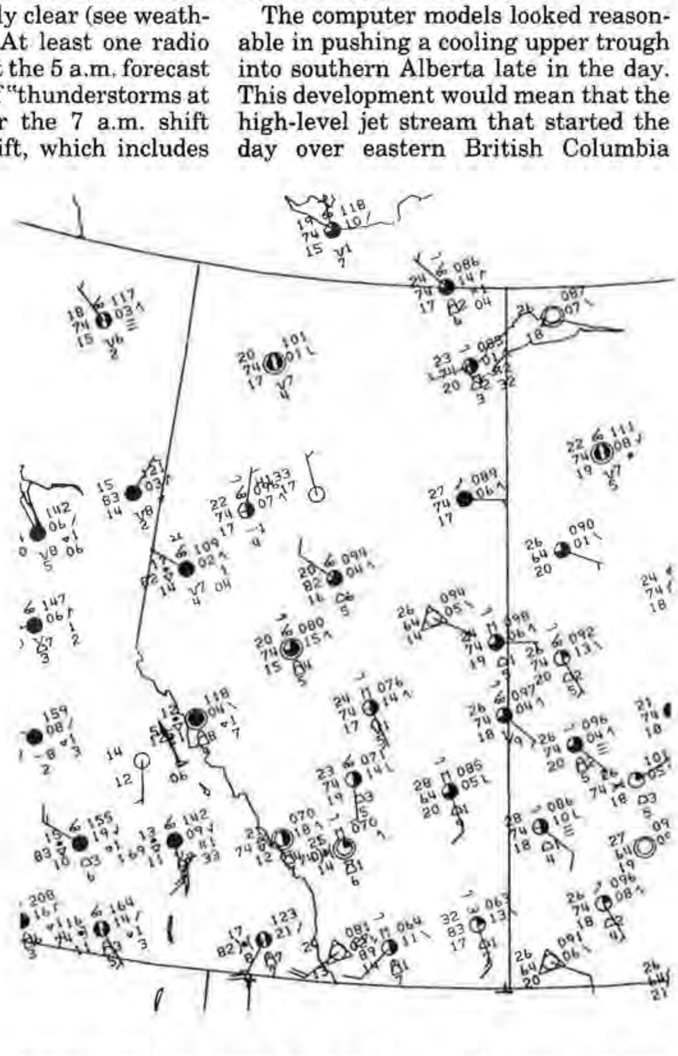


Figure 2 Surface weather plots for July 31, 1987, 1800 GMT (1200 MDT).

Figures 3 and 4 Initial sightings of the rope-like tornado near Beaumont, south of Edmonton (photo: Tom Taylor).

would shift into a south-north core over central Alberta by evening.

At the 10:15 a.m. forecast team consultation, the forecast of thunderstorms was confirmed for most regions, with a large area of severe thunderstorm potential from the southeastern Peace River district to Medicine Hat, including Edmonton, Red Deer and Calgary.

By 11:15 a.m. beeps from the lightning detection unit confirmed that thundershowers had formed over the southern Rockies. A Severe Weather Watch was issued for the Calgary and Red Deer regions.

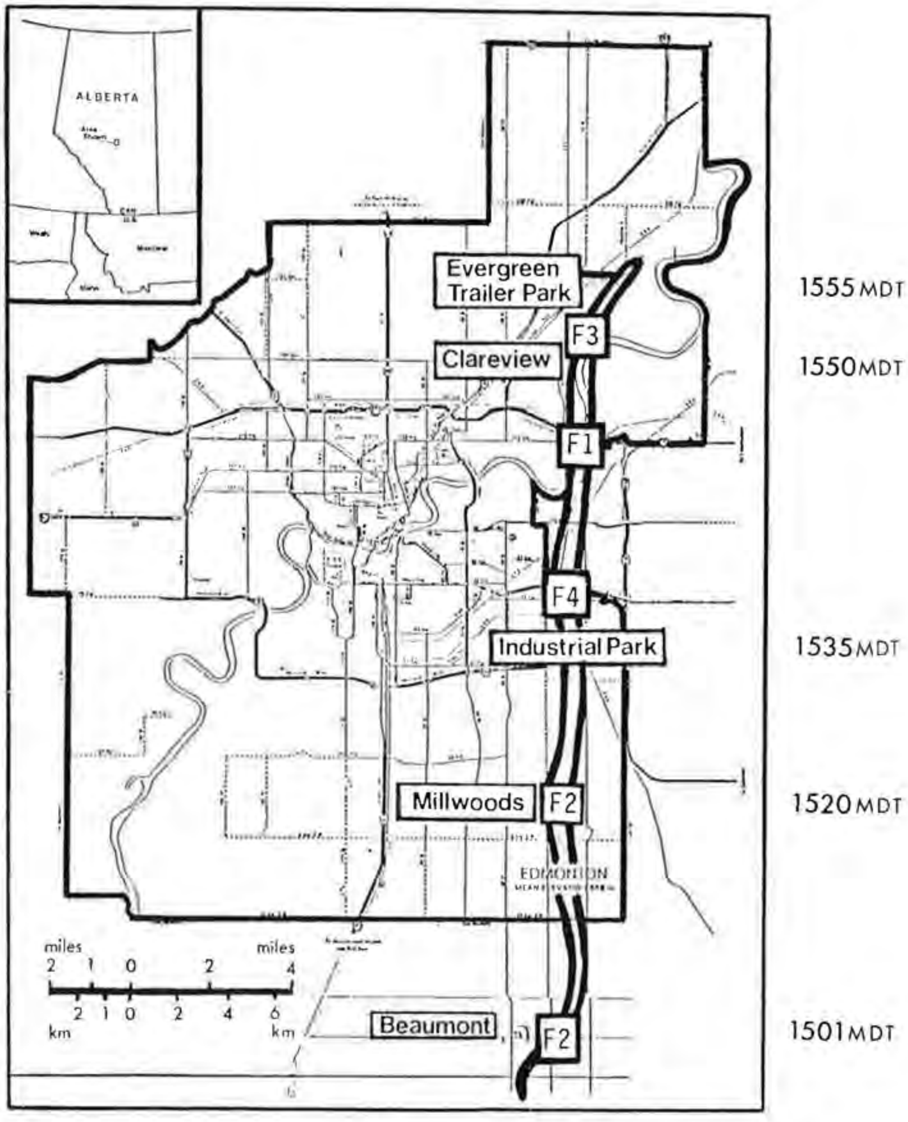
After the lightning developed northward, and weather radar and satellite imagery confirmed cumulonimbus development oriented NNW–SSE over the foothills north of Sundre, confidence rose that the severe thunderstorms forecast earlier were likely to materialize (weather map, Figure 2).

Though low-level wind flows showed an increasing southerly flow, the radar showed motion of the cells from a southwesterly direction at the surprisingly high speed of 60 to 70 km/h. That would bring them near Edmonton.

By 1:40 p.m. when the radar echoes showed tops approaching 10 km and a sustained echo strength at the second highest value, the weather watch was extended to Edmonton and adjoining regions.

By 2:45 p.m. an acceleration to 80 km/h and tops rising to 12 km were considered sufficient cause to refine the watch to a Severe Thunderstorm Warning for Edmonton City and the counties to the south and west.

Within minutes a citizen near Leduc reported seeing an apparent rope-like tornado touch down for 10 seconds and disappear (Figures 3 and 4, and back



Tornado damage path, F-scale intensities and times of occurrence at several locations.

cover, upper left). Considering the forecast severe instability and proximity to a major population area, this prompted an immediate Weatheradio Alert for the tornado warning that was composed for hard-copy transmission at 3:07 p.m. That no sooner was done than off-duty briefer, Pat Kyle, reported a tornado on the extreme southeast edge of the city. While this was relayed by Weatheradio the first tornado warning update was issued about 3:30 p.m. (Figure 5).

By this time severe-weather assistant Pat McCarthy and others were rushing back and forth to the roof of our office building, relaying visual reports of the tornado's size and direction. Like most other citizens we were mesmerized by this phenomenon and only reluctantly took cover in the basement after all power failed and the tornado passed about 2 km east of our location (Figure 6 and back cover, centre right and lower left; also satellite images on Figures 7 and 8). Before doing so, we had been able to reach the Prairie Weather Centre in Winnipeg by phone to hand over forecast responsibility to them.

We were back again within a half hour and, with emergency power, resumed forecast responsibility and issued further updates, maintaining tornado warning status until 7:00 p.m. while an equally severe thunderstorm complex approached and passed over the central and northern parts of the city. Wind gusts over 110 km/h, rain and more large hail added to the damage in and near the city.

By 8 p.m. all danger was over and warnings and watches were running down. The cold front had indeed swept through, with a vengeance! By morning a cold intermittent rain settled in on the survivors and disaster response teams working their way through the wreckage.

Figure 5 Large-size funnel as observed from Millwoods (photo: Steve Watson).

Figure 6 Destructive funnel plowing through the Industrial Area as observed from the roof of the Twin Atria Building, containing the Alberta Weather Centre (photo: Rob den Hartigh).

STORM EFFECTS

Destruction in the narrow swath swept by the tornado over the eastern edge of Edmonton was literally incredible for a city that had never experienced significant tornado damage before. During its one-hour life span it skipped along a path 37 km long varying in width from 100 to 1000 m (Map; Table 1). Heavy trucks and empty rail cars were reported completely airborne. Mobile homes, houses, and industrial sheds and plants were totally destroyed. Hailstones the size of misshapen softballs penetrated some roofs like cannonballs.

After the survey, this storm was assigned level 4 on the 5-point Fujita scale (Table 2), a value rarely exceeded in *Tornado Alley* of the US Midwest. In

Table 1 Tornado chronology, based on eyewitness accounts. Times are the best estimates available (Compiled by Al Wallace).

Time (MDT)	Movement/Location
1455	First known touchdown in the vicinity of Leduc.
1501	Beginning of the 37-km track, 3–4 km southeast of Beaumont.
1507	1–2 km northeast of Beaumont.
1515	Crossing Ellerslie Road between 34 and 17 streets.
1520	Moving through southeastern Millwoods.
1530	Northeast of Millwoods.
1535	Moving through Sherwood Park Industrial Area.
1540	Moving into the river valley near the Strathcona Science Park.
1550	Moving through eastern Clareview.
1553	Hitting farms just southwest of Trailer Park.
1555	Moving into Evergreen Trailer Park.
1600	Dissipates northeast of Trailer Park.

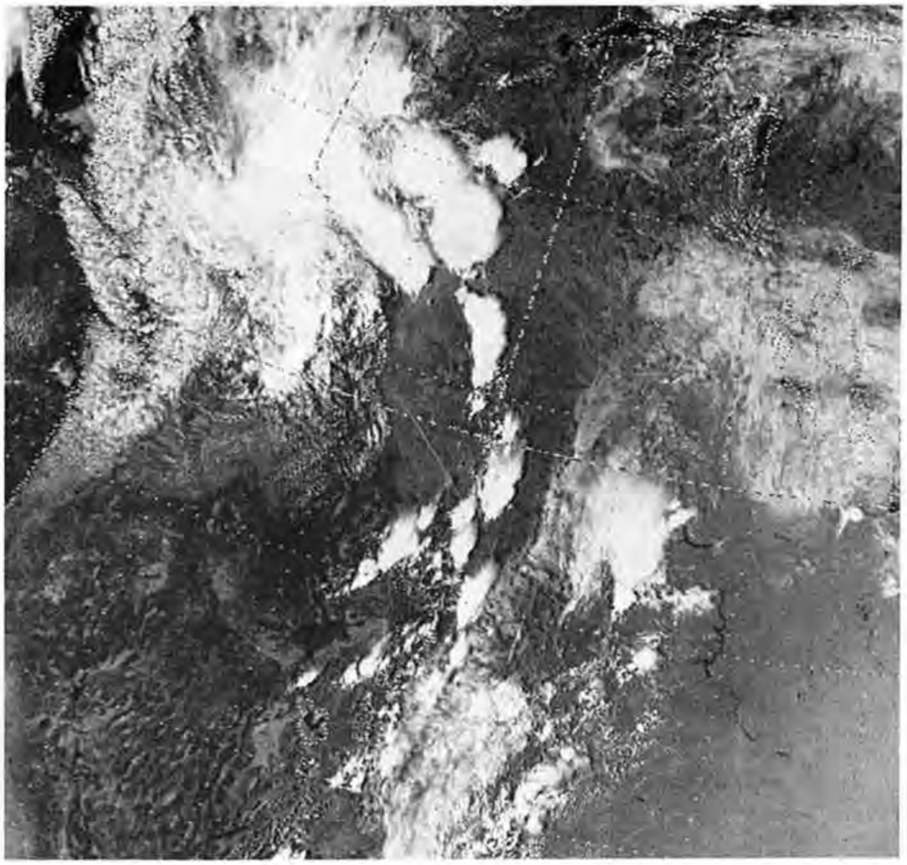


Figure 7 The near-infrared image taken by the US NOAA-9 satellite at 2149 GMT (1549 MDT or 3:49 p.m.) on July 31, 1987. The image very clearly shows the severe thunderstorm complex over central Alberta extending south into southeastern Alberta and into Montana and Wyoming. The shadows cast by the towering storms can be readily noticed on the eastern edges of the storms (Courtesy: AES Computing and Telecommunications Services Branch).

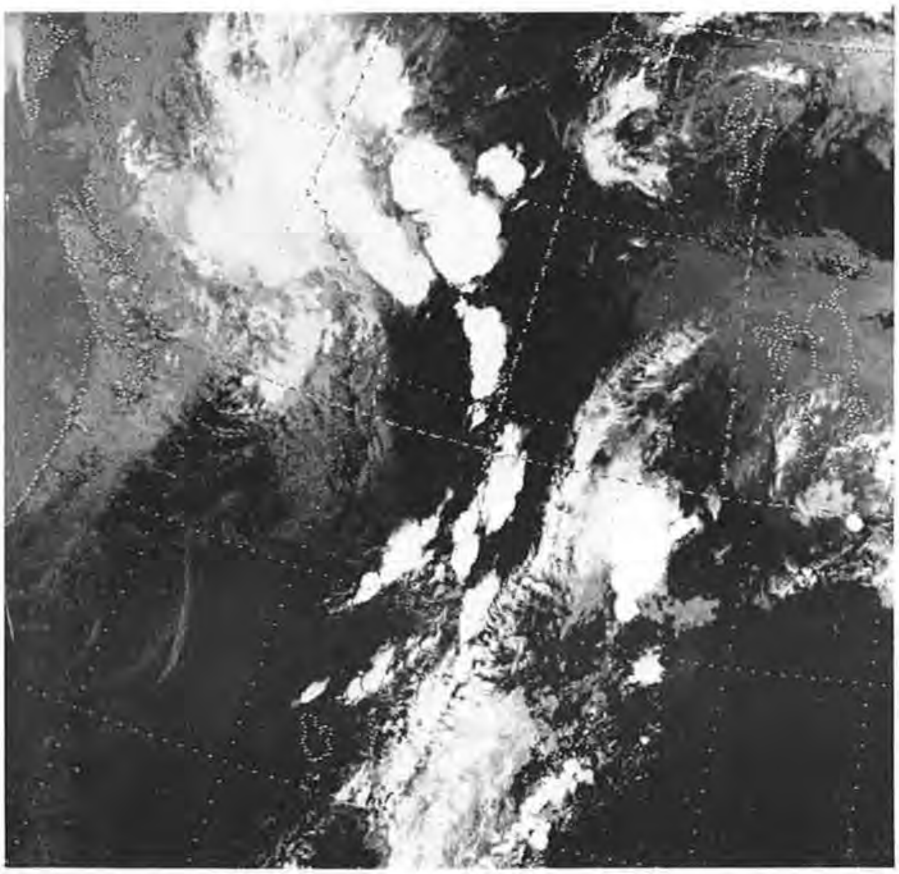


Figure 8 The 11-μm image taken by the US NOAA-9 satellite at 2149 GMT (1549 MDT) on July 31, 1987. The image shows the severe, tornado-producing thunderstorms at the same time as the near-infrared image of Figure 7. The amount of 11-μm radiation sensed by the satellite is proportional to the temperature of the emitting surface; the coldest surfaces are mapped as white while the warmest are mapped as black. The image very clearly shows the warm (low to mid-thirties degrees Celsius) Alberta landscape (black) and the very cold (-50 to -60°C) tops of the severe thunderstorms. Both satellite images show excellent examples of the various stages of thunderstorm development: a new development over North Dakota, and well developed complexes over Alberta and eastern Montana (Courtesy: AES Computing and Telecommunications Services Branch).

BACK COVER

The two articles dealing with the July 31 tornado disaster in Edmonton (pages 8–14) are supported by some striking pictures. Some of these are reproduced in colour on the back cover.

Upper Left The initial touchdown near Beaumont (photo: Tom Taylor; see write-up on page 14).

Upper Right Destruction in the Industrial Area at Nault Lumber (photo: Myron Oleskiw).

Centre Left The remains of the Evergreen Trailer Park (photo: Pat McCarthy).

Centre Right The funnel cloud moving through the Industrial Area and viewed from the roof of the Twin Atria Building, containing the AES Alberta Weather Centre (photo: Rob den Hartigh).

Lower Left The full force of the tornado is felt in the Industrial Area (photo: Rob den Hartigh).

Lower Right What remains of a house in the Ellerslie Road area, south of Millwoods (photo: Myron Oleskiw).

COUVERTURE ARRIÈRE

Ces photos saisissantes appuient les deux articles qui discutent du désastre causé par la tornade d'Edmonton du 31 juillet.

En haut, à gauche. Première observation de la tornade touchant le sol, près de Beaumont. (Photo: Tom Taylor, voir le texte à la page 14)

En haut, à droite. Destruction de Nault Lumber dans la zone industrielle. (Photo: Myron Oleskiw)

Centre gauche. Ce qui reste à l'emplacement de l'Evergreen Trailer Park. (Photo: Pat McCarthy)

Centre droit. L'entonnoir nuageux se déplaçant dans la zone industrielle, vue de l'édifice Twin Atria, demeure de Centre météorologique de l'Alberta / SEA. (Photo: Rob den Hartigh)

En bas, à gauche. La tornade fait sentir toute sa force dans la zone industrielle. (Photo: Rob den Hartigh)

En bas, à droite. Ce qui reste d'une maison dans le secteur Ellerslie Road, au sud de Millwoods. (Photo: Myron Oleskiw)

Figure 9 Tornado-ravaged houses in Millwoods (photo: Myron Oleskiw).

Figure 10 View of destruction in the Clareview area (photo: Lub Wotjiw).

Table 2 The Fujita Tornado Intensity Scale.

Scale Value	Surface Wind Speed (km/h)	Expected Damage
F0	64–116	Light
F1	117–180	Moderate
F2	181–252	Considerable
F3	253–330	Severe
F4	331–417	Devastating
F5	418–509	Incredible

the past 97 years there have been only seven other documented tornado incidents in Edmonton and these had caused negligible damage.

Twenty-seven deaths were recorded with permanent injury to at least one survivor. Damage was estimated at 250 million dollars including outright destruction and property damage, men and material costs for rescue and repair, and social assistance costs for individuals and business victims. The other severe thunderstorms that day contributed more hail, wind, and rain-related losses to the total bill.

Basically the regular forecasts and watch-warning program worked well. The few radio stations with Weatheradio reacted fastest, but mid-afternoon of the Friday preceding a long weekend is a poor time to reach listeners.

The heaviest workload came after the

Continued on page 14

THE PATH OF DESTRUCTION

by Al Wallace

Information on the physical aspects of the tornado is based on a synthesis of eyewitness reports, ground surveys and an aerial survey by Brian Smith of the University of Chicago. Adjustments may be made to the conclusions regarding timing and damage path after more information has been received.

TORNADO PATH

A tornado was sighted near Leduc at 2:55 p.m. on July 31 by a member of the public when a funnel cloud was seen to touch down and then retract (Figures 3 and 4; back cover, upper left). According to eyewitness accounts, the tornado re-formed southeast of Beaumont at 3:01 p.m. It then followed a generally northward track moving to the east of Beaumont, across the eastern fringes of Millwoods, northward to the Sherwood Park Industrial Estates (Figure 6; back cover, centre right and lower left), then to the North Saskatchewan River Valley. It followed the river northward, exiting the valley where it curves eastwards. The tornado crossed the northeastern fringes of Clareview. While crossing 153 Avenue it moved northeast to the Evergreen Trailer Park, then continued northeastward for a few hundred metres and dissipated.

The tornado was on the ground for over an hour, from its touchdown at 3:01 p.m., to its dissipation northeast of the trailer park just after 4:00 p.m. (Table 1). Based on the damage surveys, there was only one tornadic event with a path length of about 37 km and an average speed near 35 km/h. The damage path varied in width from less than 100 m to over 1000 m. In the most severely damaged areas, the width of the severe destruction varied from 200 m (Evergreen Trailer Park) to about 700 m (industrial sections).

TORNADO INTENSITY

Surveys of the damage led to this tornado being classified as an F4 on the Fujita Tornado Intensity Scale (Table 2). Along the path of the tornado (Map) varying scales of damage were visible, ranging from F0 to F4 (occasionally). Occurrences of missile damage were evident in many areas.

Beaumont Area – Ellerslie Road: 1455–1515 MDT

Little damage was visible at the funnel's first contact with the ground. After the tornado had set down again about 3 km southeast of Beaumont, only minor damage was visible. While it moved northward and strengthened, F1–F2 damage was inflicted 2 km south-southeast of Beaumont although the path width was narrow (less than 100 m). About 1.5 km southeast of Beaumont the damage was more severe (F2–F3) with the destruction of several farm buildings. The tornado appeared to have weakened as it continued northeastward then gained strength as it hit the Hilltop Dairy Farm (about 2.5 km northeast of Beaumont) at about F2–F3. Extensive roof damage to 3 new homes east of 34 Street, 1.3 km south of Ellerslie Road, indicates F2 strength. On traversing Ellerslie Road it appeared to maintain F2 strength.

Millwoods: 1515–1525 MDT *(Figure 9; back cover, lower right)*

When the tornado moved into southeast Millwoods, its damage path was 750–1000 m wide, with the most significant damage about 500 m wide. While the tornado moved north, transmission towers were toppled and trees were damaged (F2). The damage path crossed west of 34 Street at 19 Avenue. Houses along the east side of 35 Street between 20 and 22 avenues were damaged consistent with an F2 tornado. The main damage track then veered east of 34 Street to the north of 23 Avenue and continued northward. The tornado appeared to weaken to F1 as it passed northeastern Millwoods.

Industrial Area: 1525–1540 MDT *(North of Whitemud Freeway to the River Valley, between 34 and 17 streets) (back cover, upper right)*

After the tornado crossed the Whitemud Freeway, it gained strength to the F4 level. Damage was extensive and devastating within an area 600–700 m wide, from west of the CPR tracks to about 24 Street. Moderate damage extended about 1000 m wide. Within the more severely damaged zone of 600–700 m, buildings were totally destroyed, cars and trucks were picked up and moved considerable distances or suffered severe damage, steel girders were twisted, and train cars were derailed. On crossing the CNR tracks east of the Imperial Oil Refinery it weakened to F2 when it moved into the river valley near the Strathcona Science Park. (Note the satellite images in Figures 7 and 8 are for 1549 MDT.)

Clareview: 1540–1555 MDT *(Figure 10)*

The tornado then moved parallel to the river valley at F1-F2 strength causing moderate tree damage, and followed the river valley east of Clareview. Roof damage was evident east of 24 Street between 120 and 137 avenues, tree damage and some structural damage was evident in Hermitage Park and a drive-in theatre was destroyed near 24 Street/137 Avenue (F1–F2). The greatest devastation occurred along 19 Street between 145 and 147 avenues where 3 houses (2-storey) were completely demolished and many others had considerable damage. At this point the tornado was F3 approaching F4. Just to the east of the destroyed houses, 4 large steel hydro towers were twisted and knocked down. To the west (21 Street) F1 roof damage was evident. The general damage width was again up to 1 km wide, while severe damage was limited to about 300 m. The tornado moved northeast from Clareview around 19 Street/ 153 Avenue and weakened rapidly. Only minor tree damage (F0) was apparent.

Evergreen Trailer Park: 1555–1605 MDT *(back cover, centre left)*

About 500 m southwest of the Evergreen Trailer Park the tornado once more strengthened (F2–F3) as it struck 3 farms, destroying a mobile home and causing extensive severe damage to buildings, vehicles and trees. The tornado then devastated the trailer park destroying 133 mobile homes and considerably damaging another 39. Frequent missile damage was observed. The path of total destruction was about 200 m wide during this F3 stage. The tornado left the eastern end of the trailer park about 300 m north of the 1 Street/167 Avenue intersection. The tornado quickly dissipated a few hundred metres beyond the trailer park.

Al Wallace joined the Atmospheric Environment Service as an operational meteorologist in 1974. Since that date he has worked as a forecaster in Ontario and an instructor with the meteorologist training course, and has been engaged in applied forecasting research. He is currently the Summer Severe Weather Supervisor at the Alberta Weather Centre in Edmonton, Alberta.

Forecaster Tells Tornado Story

Continued from page 12

event. Supervisors right on up to the regional director spent the weekend and much of the next ten days answering a flood of media enquiries. With no previous experience some local commentators did not comprehend the virtual impossibility of predicting the initiation of an individual tornado. We were pleasantly surprised, though, by many positive comments that began to get publicized from meteorologists in Canada and the United States. This attention also provided the best demonstration that Weatheradio is by far the best way of disseminating tornado warnings and updates for the major urban centres that it serves. Those commercial radio stations who monitor Weatheradio were clearly in the forefront with the warnings and updates. Sales to the other broadcast media and local emergency reponse centres should escalate.

FURTHER READING

Borsu, J., 1987: Edmonton Tornado: The Federal Government's Response. *Emergency Preparedness Digest*, Emergency Preparedness Canada, Ottawa, Ont., pp. 2–11.

Environment Canada, 1987: The Review of the Weather Warning System Associated with the Edmonton Tornado of July 31, 1987. Atmospheric Environment Service, Edmonton, Alta.

Garry Atchison is a senior meteorologist who has been with the Canadian Weather Service for 23 years and has served at the Alberta Weather Centre since 1980. Mr. Atchison was the severe weather forecaster at the Centre on that tragic day.

This article is reprinted from *Zephyr*, October 1987, published by the Atmospheric Environment Service.

RÉSUMÉ *Au cours de l'après-midi du 31 juillet 1987 une tornade dévastatrice frappe la ville d'Edmonton. Cette violente tempête cause la mort de 27 personnes et en blesse des centaines d'autres; en plus, elle provoque des dommages matériels s'élevant à plus de 300 millions de dollars.*

D'une force F-4 selon l'échelle Fujita, la tornade produit des vents s'élevant jusqu'à 417 km/h et entraîne une destruction incroyable dans l'extrême est de la ville. Elle dure près d'une heure et se déplace sur une distance d'environ 37 km; sa trajectoire est large de quelques centaines de mètres à 1300 m; elle apparaît sous plusieurs formes et produit de nombreux tourbillons. En plus de la tornade, la violente tempête produit une large bande de grêle qui endommage maisons et véchicules; le plus gros grêlon mesuré a un diamètre de 10 cm.

Durant la dernière semaine de juillet, le temps est orageux. La masse d'air chaud et humide sur l'Alberta provoque des orages violents presque quotidiennement; on compte un nombre record d'éclairs et, le 30, on détecte 46 000 décharges des nuages au sol. Il est significatif de noter que, pendant cette semaine, 14 tornades surviennent.

Il n'est donc pas surprenant que l'on prévoit encore des orages violents le 31. Tôt en journée, on émet des avis de temps violent. Lorsque le radar montre une ligne d'orages qui se développent très rapidement en se déplaçant vers Edmonton, on émet un avertissement de temps violent pour alerter le public du danger imminent. On reçoit le premier rapport d'une tornade, près de Leduc, vers 15 h 00, ce qui entraîne la diffusion immédiate d'un avertissement de tornade. La tornade continue vers le nord à une vitesse de 35 à 40 km/h, détruisant tout sur son passage jusqu'à sa dissipation, passé l'emplacement de l'Evergreen Trailer Park, aux environs de 16 h 00.

Plus tard, une deuxième ligne d'orages, accompagnée de vents destructeurs de 110 km/h et de nuages en entonnoir, passe au-dessus d'Edmonton à 18 h 00. Le même jour, en plus de la tornade d'Edmonton, on compte 4 autres tornades dans le centre de l'Alberta. Celles-ci, ainsi que celles survenues plus tôt dans le mois, sont relativement faibles et frappent des régions rurales peu peuplées.

La période estivale albertaine est souvent marquée par la présence d'orages violents. Quoique moins fréquentes, on a quand même observé une moyenne annuelle de 18 tornades au cours des cinq dernières années.

TOM TAYLOR, TORNADO HERO

One of the heroes of the Edmonton tornado was Tom Taylor, a pharmacist from Leduc, Alberta, about 24 km southeast of the afflicted city. Mr. Taylor had just come in from feeding his black retrievers in the kennel outside when he saw thick, black rain clouds over his house. For fifteen seconds from the loft of his house, which stands on an archeological site high on a hill, he saw a low-hanging cloud to the southwest with a "snake-like" funnel pointing towards the ground. At the same time high winds were kicking up debris. Taylor, trained to be observant in his job (he sometimes files narcotics reports for the police), picked up the phone and called the Alberta Weather Centre informing them "things are pretty hectic right now". He told them that the cloud's funnel had just hit the ground. The time was approximately 2:55 p.m. The Weather Centre, which had been expecting severe weather, immediately put out a tornado warning. Half an hour later, the full fury of the tornado pounded one of Edmonton's principal industrial districts.

Tom spent most of his time in the loft. He didn't have time to head for the basement. But if he had to do it all over again he would have used the below-ground extension phone. His wife and children were in Edmonton. They felt the full force of the tornado. Little did they know that Mr. Taylor had been the very first person to spot the tornado and report it promptly to the Weather Centre.

Naturally AES staff were delighted with Mr. Taylor's prompt action. Says AES Western Region director Brian O'Donnell "It was on the basis of Mr. Taylor's report that the tornado warning was issued for Edmonton. His quick action resulted in more warning time for the citizens of the city." Mr. Taylor has now agreed to become a volunteer under the AES Severe Weather Watch program.

Taylor says he has been interested in weather since he was a child. He has a close friend who works with the Alberta Hail Program. He listens to weather forecasts at least three times a day and has a Weatheradio Canada receiver. "I'm a country person. Call me a farmer with a weather eye if you wish".

On November 26, 1987 the federal Minister of the Environment, The Honorable Tom McMillan, presented Mr. Taylor with a framed letter of appreciation for his superb initiative. One of Mr. Taylor's photographs was awarded a prize in the AES *Canadian Weather Trivia Calendar* contest.

This article is reprinted from *Zephyr*, October 1987, published by the Atmospheric Environment Service.

UNDERSTANDING CO_2 AND CLIMATE

Until recently, the debate about how humans are changing the structure and composition of the earth's atmosphere has been a scientific one. Now, year by year, as our understanding of the related implications for society and its future welfare slowly improves, the issue is becoming a major concern of policy makers. Recent research activities, both internationally and nationally, have contributed substantially to this awakening.

THE EARTH'S ATMOSPHERE:
Are We Changing Its Composition?

Evidence of the effects of human society and its activities on the earth's atmosphere continues to accumulate; for example:

- Atmospheric concentrations of the most abundant greenhouse gas, carbon dioxide (CO_2), are increasing by 0.4% a year. CO_2 emissions from the burning of fossil fuels for energy, the primary source for its increased atmospheric concentrations, appear likely to escalate at an average annual rate of about 1% until at least A.D. 2050. The energy policies of the international community will be a major factor in determining the magnitude, and even the direction, of such trends, particularly beyond A.D. 2050.
- Atmospheric methane, a secondary but very effective greenhouse gas, is increasing annually at about 1% and has almost doubled in concentration during the past several centuries. Increasing trends in the global population of domestic animals and increases in the land area covered with rice paddies, both important sources of methane, suggest the atmospheric concentrations of this gas will continue to rise unabated.
- Other trace gases, lower in concentration but of significant importance to global climates, are increasing at annual rates of up to 6%. These include nitrous oxide, surface ozone and chlorofluorocarbons (freons).
- Winter concentrations of aerosols in the lower levels of the Arctic atmosphere are increasing, affecting the heat energy balance of the Arctic climate. The long-range transport of air pollutants from Europe appears to be the primary cause.

CLIMATIC RESPONSE:
How Will Changing Atmospheric Composition Affect Climate?

Changes in the atmospheric composition, as described above, are expected to cause major alterations to the earth's climate. Recent studies suggest that

- A doubling of atmospheric CO_2 concentrations, or its equivalent, may increase average surface temperatures of the earth by 3.5 to 4.2°C, well into the upper range of earlier projections. Such a warming would be larger than any climate change experienced on earth during the past 10,000 years (Figure 1).
- An increase of 1°C over the temperatures during the nineteenth century could occur by A.D. 2000. Global climate records suggest that a warming of 0.3–0.7°C has already happened, with the three warmest years on record occurring during the 1980s.

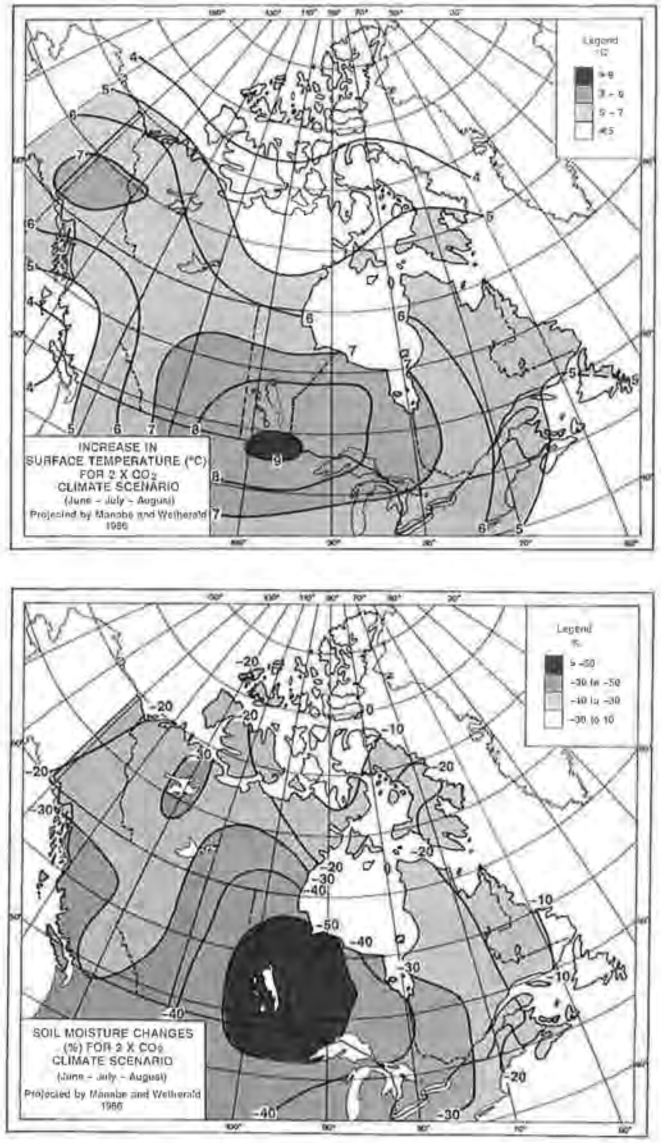


Figure 1 Scenarios for a 2 × CO_2-type climate over Canada as projected by the Geophysical Fluid Dynamics Laboratory, Princeton, N.J., in 1986.

- Warmer climates are likely to reduce mid-continental cloudiness over North America in summer, thus amplifying summer warming and dryness. Within the next half century, central Canada could experience a midsummer warming of as much as 9°C, with a corresponding 50% reduction in soil moisture.
- Past climates indicate that the primary consequence of a major global warming is likely to be a large-scale redistribution of global freshwater resources.

IMPLICATIONS OF AN ENHANCED GREENHOUSE EFFECT:
How Will We Be Affected?

The effects on society of higher CO_2 concentrations, warmer global climates, and related changes are complex and difficult to assess. Some humans will benefit, others will suffer. Ongoing studies into how natural ecosystems and hence how humans are likely to react to global change are gradually adding to the knowledge base required by policy-makers for appropriate response. Recent results include the following:

- The growth and drought resistance of plants improve as the atmospheric CO_2 concentration increases. Although the response of vegetation in natural, competitive environments is not well understood, experiments in growth chambers under controlled environments suggest that these improvements could be substantial.
- Under warmer climates, Prairie agriculture would on average experience modest decreases in productivity, but could encounter serious problems during more frequent years of severe drought.
- In Ontario, the adverse economic effects resulting from increased aridity in southern regions, lower lake levels, increased severity of fires, diseases and pests and the likely collapse of the winter skiing industry would be partially offset by the benefits of long growing seasons, year-round shipping in ice-free waters, reduced space-heating costs and improved summer tourism potential. The net annual economic loss to Ontario due to a doubled CO_2-type climate could exceed $100 million.
- Rising sea levels due to climate warming would pose a significant threat to coastal Canadian cities. If such rises were to exceed 1 metre, storm surges with 20-year return periods would inundate the new Convention Centre, a number of major commerical complexes, and several hundred homes in Charlottetown, P.E.I. Similar rises would affect major sewage treatment facilities, transportation corridors and a power plant in Saint John, N.B.

POLICY IMPLICATIONS:
How Should We Respond?

The effects of human activities on the planet's atmospheric life-support system and the implications of related changes for humans are emerging as major international policy issues. Yet the understanding of the problem is still very limited and subject to controversy, and hence becomes a major obstacle to timely and responsible policy action. Studies into this dilemma suggest the following:

- Aggressive international research efforts to advance the level of understanding must continue, and merit the active support of national and international governments.
- Decision-makers dealing with social and economic activities sensitive to climate, particularly those extending several decades or more in the future, need to include the prospect of climate change in their considerations now.
- Decision-makers must begin to recognize the unescapable relationship between economic development and the environment in their policy formulations. Energy policies in particular must promote strategies consistent with the concept of a sustainable environment.
- Canadians, among the highest per capita emitters of CO_2 in the world, have a great potential for improving the efficiency of their use of energy.
- Public awareness and the development of a new environmental ethic are important factors in achieving effective policy changes.

This report is adapted from Environment Canada's Annual Report 1986: Understanding CO_2 and Climate (August 1987), a periodic report summarizing current events in CO_2 climate research. The material was prepared and made available by Henry Hengeveld, the Atmospheric Environment Service advisor on carbon dioxide related matters.

Comprendre le CO_2 et le climat

La projection des émissions futures de CO_2 dans l'atmosphère semble indiquer au minimum le doublement ultérieur de la concentration de CO_2 dans l'atmosphère par rapport aux niveaux pré-industriels. Toutefois, l'époque où surviendra un tel doublement est difficile à établir, car le comportement humain à long terme en matière de consommation d'énergie est en grande partie imprévisible. En outre, il est probable que la concentraion des autres gaz de serre s'accroît de beaucoup au cours des futures décennies, d'ou un renforcement des effets climatiques de la hausse des niveaux de CO_2. Un effet combiné sur le climat qui équivaudra au doublement de CO_2 se manifestera sans doute dès l'an 2030 et, fait très probable, d'ici à l'an 2050.

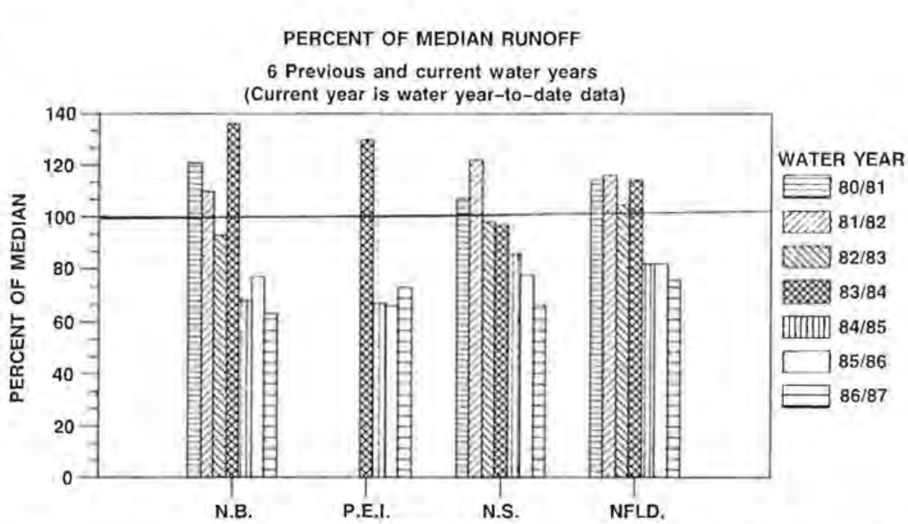
Les scientifiques de l'atmosphère avancent maintenant que les changements susmentionnés entraîneront sans doute un réchauffement climatique mondial supérieur à tout changement jamais observé par l'humanité. Il est probable qu'un tel réchauffement s'accompagnera des phénomènes suivants : réchauffement amplifié aux régions de haute latitude en automne et en hiver; étés plus secs aux latitudes moyennes de l'hémisphère nord; augmentation de l'humidité disponible dans les régions polaires; hausse éventuelle de 0,2 à 1,4 m du niveau moyen de la mer à l'échelle mondiale.

Des études préliminaires des implications d'un réchauffement climatique important appuient cette conclusion : existence de profondes répercussions sur les écosystèmes, l'agriculture, les ressources en eau et la glace de mer du globe. Les pays appauvris du monde en voie de développement sont moins aptes à répondre à un tel changement et, de ce fait, plus vulnérables aux conséquences catastrophiques éventuelles. De grands secteurs de la population du monde seront aussi touchés par une hausse de 1 m du niveau de la mer. Au sein du Canada, l'agriculture bénéficiera beaucoup de saisons de croissance plus chaudes et plus longues, en particulier dans les régions du nord : les effets directs d'une quantité accrue de CO_2 pourraient accroître de 15 p. 100 la croissance des cultures de plein champ; l'agriculture des régions du sud pourrait être très touchée par une augmentation de la fréquence et de la gravité de la sécheresse; les saisons des glaces des Grands Lacs disparaîtront peut-être; la baisse du ruissellement des eaux du bassin des Grands Lacs pourrait réduire de 20 cm le niveau des lacs; de grands marécages d'intérêt écologique, comme celui de Point Pelee, disparaîtraient ou seraient profondément modifiés; on pourrait assister à la fin des saisons de neige fiables dans le sud de l'Ontario.

SUMMER OF '87 IN REVIEW

by Amir Shabbar

The season was anything but placid and one to be long remembered across Canada.



The summer of 1987 (June-July-August) set some long-term records. The heat wave that covered southern Ontario and Quebec brought back memories of the heat waves in the 1940s and 1950s. Canada's worst natural disaster surprised Edmontonians when a violent tornado slashed a vicious trail of death and destruction through their city on July 31. Scanty rainfall resulted in record-low river levels and dry wells in the Maritimes, where water rationing was imposed in some communities. July rains averted an onset of drought on the Prairies; further it was excessively dry on the West Coast.

TEMPERATURE

A vast stretch of the country from the British Columbia Coast to the St. Lawrence Valley and the High Arctic enjoyed temperatures about a degree above normal. Southern Alberta and southern Saskatchewan experienced a slightly below normal summer. Most of the Maritimes and the Territories had readings from near normal to 1°C below normal. Southern Ontario sweltered through two heat waves during June and July, when maximum temperatures climbed above 30°C and the humidex registered an uncomfortable 40°C on 14 days.

The highest and lowest temperatures occurred in June: 39.1°C at Lytton, B.C.; −14.2°C at Cambridge Bay, N.W.T.

PRECIPITATION

Areas from eastern Ontario to the East Coast experienced a drier summer than usual. Summer precipitation was less than 75% of normal in the Atlantic Provinces, in some southern Newfoundland communities amounting to less than half of normal. Charlo, Moncton and Fredericton received record-low July precipitation, from 20 to 40 mm. At Sydney, it was the driest July since 1937. The West Coast, the northern interior valleys of British Columbia and the Mackenzie Valley were also dry. Communities in these areas had from one half to two thirds of their normal summer rainfalls.

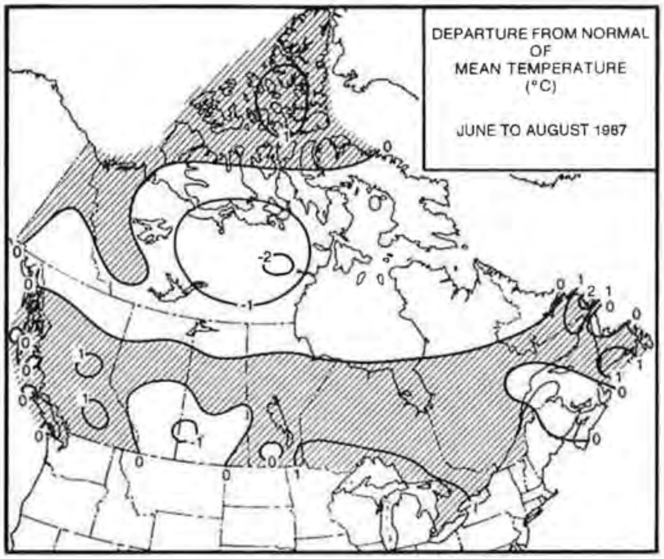
Most of the Prairies, Ontario and the Territories had ample rainfall. Precipitation was from 100 to 150% of normal. Deluges (200 to 300 mm) inundated the Grande Prairie and Edson Forest Districts during the last two days of July. During mid-August, southwestern Manitoba received a "once-in-a-lifetime" rainfall when 120 to 140 mm fell in a 24-hour period.

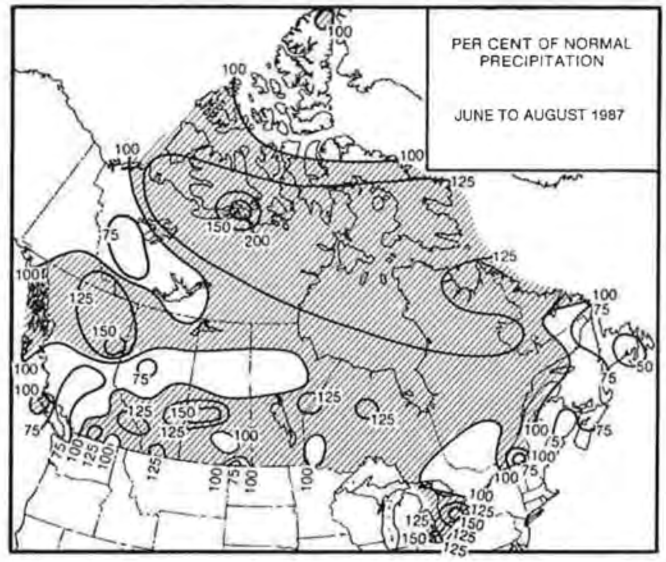
SIGNIFICANT CLIMATIC IMPACTS

The unusually dry summer created problems in the Atlantic Provinces when wells dried up and lake and river water dropped to record, low levels. Travel in the woods was banned in western Nova Scotia, and owing to the heightened fears of forest fires a permit was required to camp and picnic. Sheep farmers found their herds vulnerable to coyote attacks while sheep roamed farther afield in search of watering holes and grass. In Newfoundland, 1,500 workers were laid off in the forestry industry after the forest fire hazard index rose to extreme levels.

Throughout most of July, central Canada baked during a record-breaking heat wave, when daytime temperatures soared above 30°C. Ontario had its hottest July in 33 years while a tropical brand of air mass covered the Province. Maximum temperatures exceeded 30°C on 14 occasions in Toronto – its greatest number of "hot days" in 67 years. Moreover, the extensive use of air conditioners set a record for daily electrical consumption in the city. Toronto experienced its sixth warmest summer since the start of records in 1840. The heat was beneficial for most Ontario crops, particularly corn and soybeans. After a dismal summer in 1986, farmers were reaping a bumper crop by the end of summer.

On several occasions, a clash between the hot and humid air from the south and the cooler and drier air from the north resulted in outbreaks of violent summer thunderstorms and tornadoes in southern Ontario and southern Quebec. On July 14, a series of intense thunderstorm cells dropped over 100 mm of rain in a 2-hour period on Montréal. Main expressways and basements were flooded throughout the city. Some roads were submerged under 4 metres of water and motorists had to be rescued from their vehicles. Damage estimates from the flooding exceeded $200 million. On July 24, a wave of destructive thunderstorms lashed southern Ontario, where lightning hit a YMCA camp near Bala (north of Orillia) and 15 campers were sent to hospital. Tornadoes at Sebright and in Missis-





A fireman lends a helping hand to motorist Pierre Corbeil on Décarie Expressway. *Gazette,* Pierre Obendrauf.

Aftermath of the Mississauga tornado outbreak on July 24, 1987.

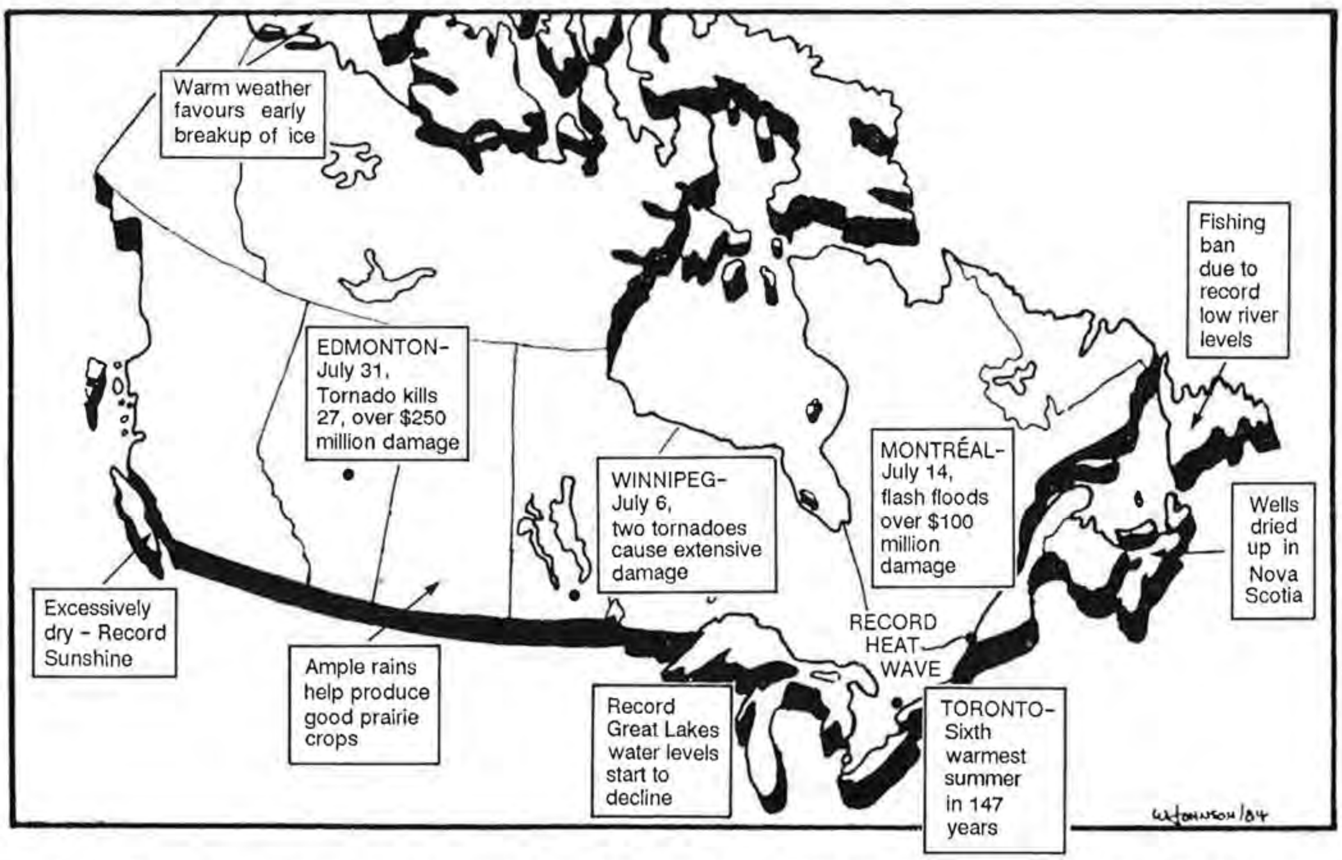
sauga caused extensive structural damage to buildings the same day.

The warm and dry weather helped to lower the record-high water levels in the Great Lakes. The declining lake levels significantly reduced the risk of fall flooding along the shorelines.

After a very dry spring on the Prairies, July rains provided much needed moisture for crop growth. The rains averted what had been shaping up as yet another catastrophic growing season for the Prairie farmers. Hailstorms, damaging winds and sudden downpours are common in summer on the Prairies. This year was no exception. On July 6, two tornadoes touched down in the southern part of Winnipeg. The winds caused considerable damage, and over 40 mm of rain in 2½ hours caused flash floods. Heavy rains in the 200 to 300 mm range inundated the Grande Prairie and Edson Forest Districts during the last two days of July. Rain-swollen rivers washed out roads and bridges, and huge tracts of farmland were waterlogged. The most destructive summer weather was a killer tornado that struck Edmonton on July 31, the second worst tornado disaster in

Many cars were stalled by floods, but this one was smacked by a tree on Décarie Blvd. *Gazette,* James Seeley.

Canadian Coastguard icebreaker *Labrador* navigating in Arctic waters.



Canada (the Regina cyclone in 1912 had claimed 28 lives). It slashed a vicious trail of death and destruction in the agricultural, industrial and residential areas of Strathcona County and in Edmonton's eastern subdivisions. The Evergreen Mobile Home Park in northeastern Edmonton felt the brunt of the storm when the tornado ripped through the park turning it into a field of chipwood and mangled metal. In all, 27 people lost their lives, over 200 were injured and property damage exceeded $250 million.

Sunshine abounded on the West Coast, where Victoria received a record 348 hours of bright sunshine during August. Although many West Coast residents enjoyed the long stretches of sunny and dry weather, residents on Galiano and Gabriola Islands, located between Vancouver Island and the mainland, saw their wells dry up, even forcing them to ration their bath water.

The warm weather and favourable winds sped up the ice breakup and allowed crews to drill for oil in the Beaufort Sea.

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