Chinook

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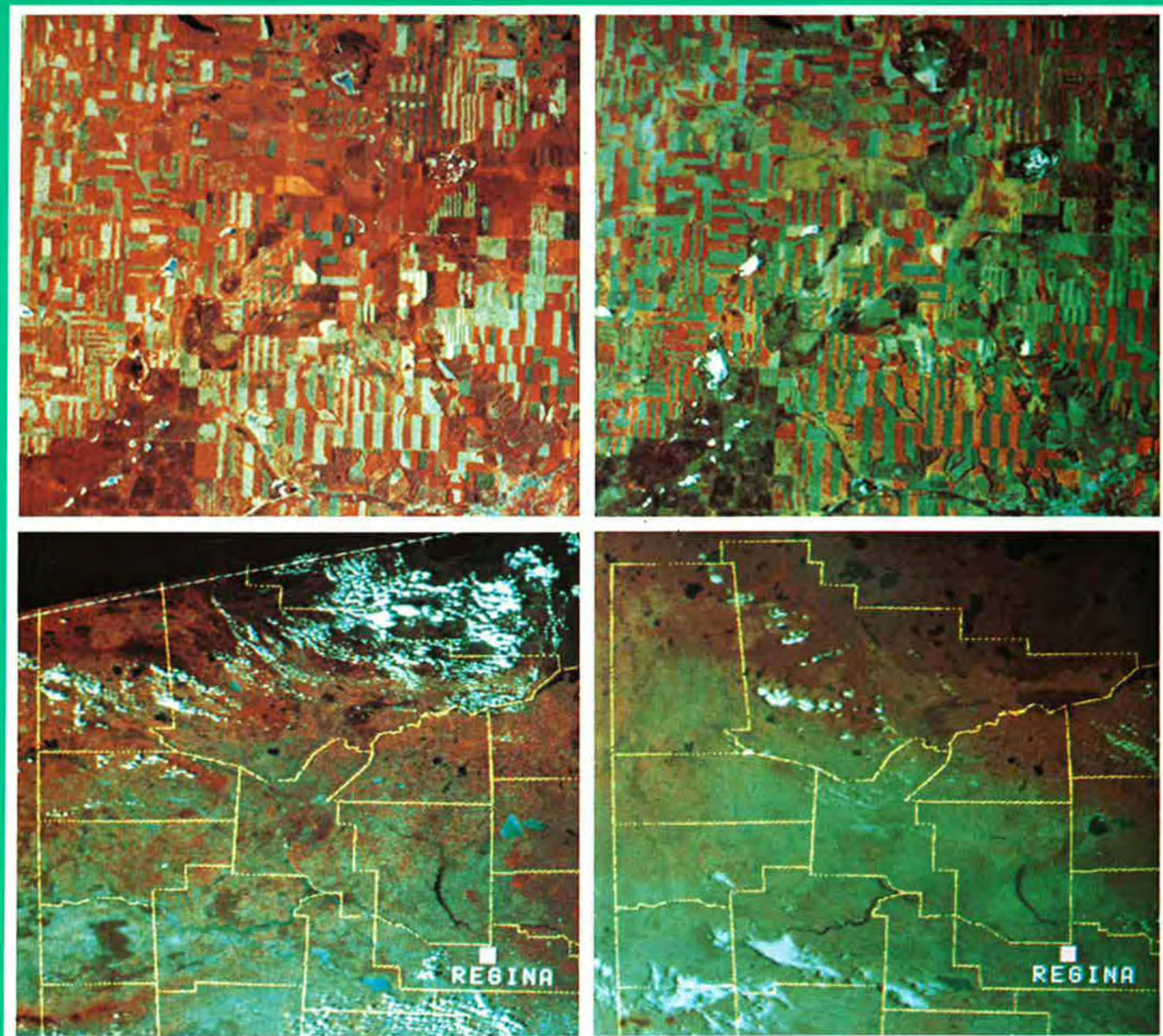
SUMMER 1984



INSIDE: PRAIRIE DROUGHT 1984

Chinook

Summer 1984 Volume 6 Number 3

ARTICLES

DEPARTMENTS

FROM THE EDITOR'S DESK

The first meeting of the *Chinook* Editorial Board took place in Toronto on October 30, when the terms of reference and the action plans were approved.

The Winter issue (Volume 6, Number 4) will be out in a couple of weeks, while the four issues of Volume 7 (1985) will be in the mail toward the ends of February, May, August and November, 1985.

The Board is committed to publish more articles in French and also to provide a brief summary at the end of each article in the other official language.

With time we hope to increase the number of departments and features and also the number of pages per issue.

We look forward to your comments and suggestions. It is important to us and the Society to know the readers' reactions to and expectations for the magazine. We will try to share some of your comments and observations with our readership.

It goes without saying that your written contributions are also welcome. The Guidelines for contributors of articles to *Chinook* will be published in the next issue.

Hans VanLeeuwen
Editor

SATELLITE SEES DROUGHT
by Oscar Koren

The LANDSAT and NOAA satellite images for 1983 and 1984 on the cover were produced by the Canada Centre for Remote Sensing of the Department of Energy, Mines and Resources in cooperation with Statistics Canada. In each photograph the quantity of vegetation is directly related to the degree of redness. A deeper red indicates more vegetation; a lighter red, less vegetation. Areas affected by drought are clearly shown in either set of photographs by comparing the 1984 image with the corresponding 1983 image.

The upper photographs are LANDSAT images for 2 August 1983 (left) and 27 July 1984 (right). Swift Current is located in the lower right of each image. The lower photographs are NOAA images for 2 August 1983 (left) and 1 August 1984 (right). Crop District boundaries are outlined for reference.

Oscar Koren is a meteorologist with the Field Services Directorate of the Atmospheric Environment Service in Toronto who is interested in the meteorological applications of satellite data.

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THE COVER

The satellite images of the Canadian Prairies for 1983 and 1984 clearly show the extensive areas affected by drought during 1984. For details see the account on this page.

THE PRAIRIE DROUGHT OF 1984

by Ron F. Hopkinson

Dry conditions across the southern Prairies made national headlines during the summer of 1984. Drought had struck again, but no one was too surprised. Droughts of varying areal extent, duration and intensity have been recorded on the Prairies from the early 19th century when settlers first arrived in Manitoba and attempted to forge a living from the land. When Captain John Palliser commanded an expedition to the Prairies in 1857 and 1858, the open grasslands of southwest Saskatchewan and southeast Alberta were described as arid and unsuitable for agriculture. In this century droughts have occasionally caused great hardship particularly following the widespread settlement of Saskatchewan and Alberta.

Drought is an aspect of the climate that affects all areas of the world but in arid regions such as the Canadian Prairies, it is a frequent visitor. Farm practices have been developed to lessen the impact of moderate drought, but several severe occurrences of the past decade have reminded the Prairie people that modern society is still very much subject to the whims of nature. Indeed, if the drought of the 1930s occurred today, its impact could still cripple the Prairie economy and possibly lead to farm abandonment in those areas most seriously affected. With the need for water increasing with the general development in other economic sectors, Prairie drought could have serious implications beyond the normal agricultural ones.

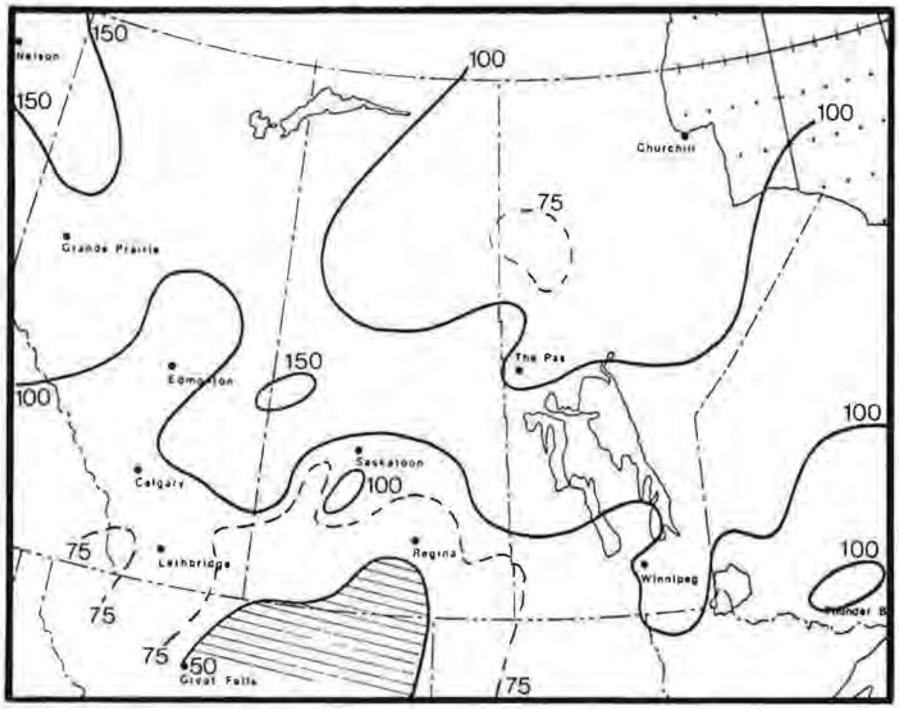
Defining drought has presented climatologists with a dilemma. Of course much below normal precipitation is an element of drought, but at what point does drought begin? Drought impacts can materialize in as little as a few weeks when no precipitation coincides with the heat and sun of high summer. On a longer time-scale, a precipitation deficit over the summer season can lead to declining surface water supplies, major crop yield reductions, loss of hay, and unproductive pastures. If the precipitation shortfall extends over a year or years, the water table declines and crops have insufficient moisture to grow and mature properly. Perhaps these factors determine the intensity of the drought. Droughts may occur over a broad range of spatial scales from individual fields to regions or a subcontinent. The Prairie drought of 1984 was subregional since northern areas received excessive moisture. Thus, the 1984 drought in Canada was intense but restricted to southern Alberta and Saskatchewan and southwest Manitoba. Even in this area, the character and intensity of the drought varied considerably.

Wind erosion from a seeded field east of Regina in May, 1984 (Courtesy: PFRA - Regina).

On the Prairies many aspects of the hydrologic cycle may act in concert to produce drought. For agriculture, the timing of summer rains is often more important than the total rainfall over the growing season. Winter precipitation is also important. The lack of snow cover allows surface soils to dry out and leads to low run-off in the spring. This run-off is required to fill sloughs, dugouts, reservoirs, and natural lakes. Most run-off on the Prairies is derived from snowmelt. Low streamflow directly affects hydroelectric production, irrigation, water quality, recreation, wildlife, fisheries, and transportation. Prolonged hot, sunny weather places additional stress on water resources through increased evaporation.

The cumulative nature of drought appears to have contributed to the crisis in 1984. With the exception of the winter 1981–1982, the last five winters each produced no more than 75 per cent of the normal precipitation over the southern Prairies. The winter 1983–84 was preceded by a very dry fall when precipitation was less than 50 per cent of normal over most of southern Alberta and southwest Saskatchewan. During the summer of 1983, this same area received about 75 per cent of normal rainfall.

The southern portions of Alberta and



Precipitation for the period April 1, 1984 to October 1, 1984 expressed as a per cent of normal (Courtesy: AES Central Region).

Saskatchewan were identified in the spring of 1984 as areas of very low soil moisture. The soils may be thought of as a many layered reservoir. Moisture in the surface layer (10 cm deep) is needed for crop germination. Without regular rainfall this layer dries out rapidly. Some areas had poor surface soil moisture conditions, but of greater concern was the subsurface soil layer (10 to 120 cm), a deeper reservoir tapped by the crop root system. It sustains plant growth and responds more slowly to precipitation or dry spells. The practice of summerfallow is used to build up the moisture reserves in this layer by minimizing the main loss, evapotranspiration from crops and weeds. The cumulative effect of below average precipitation since the summer of 1982 led to the low subsurface soil moisture conditions observed in the spring of 1984. Ground water in shallow aquifers and eventually deep aquifers requires replenishment from the surface. Farms and small communities that were dependent upon shallow ground water supplies experienced some difficulties with declining ground water levels in 1984.

The 1984 run-off on the plains was minimal because of the shallow snowpack. Thus recharge of surface water projects was limited while sloughs and dugouts were low and in some cases, dry. The snowpack in the mountain headwaters of the North and South Saskatchewan Rivers was below normal so even the major rivers were likely to experience low flows in 1984.

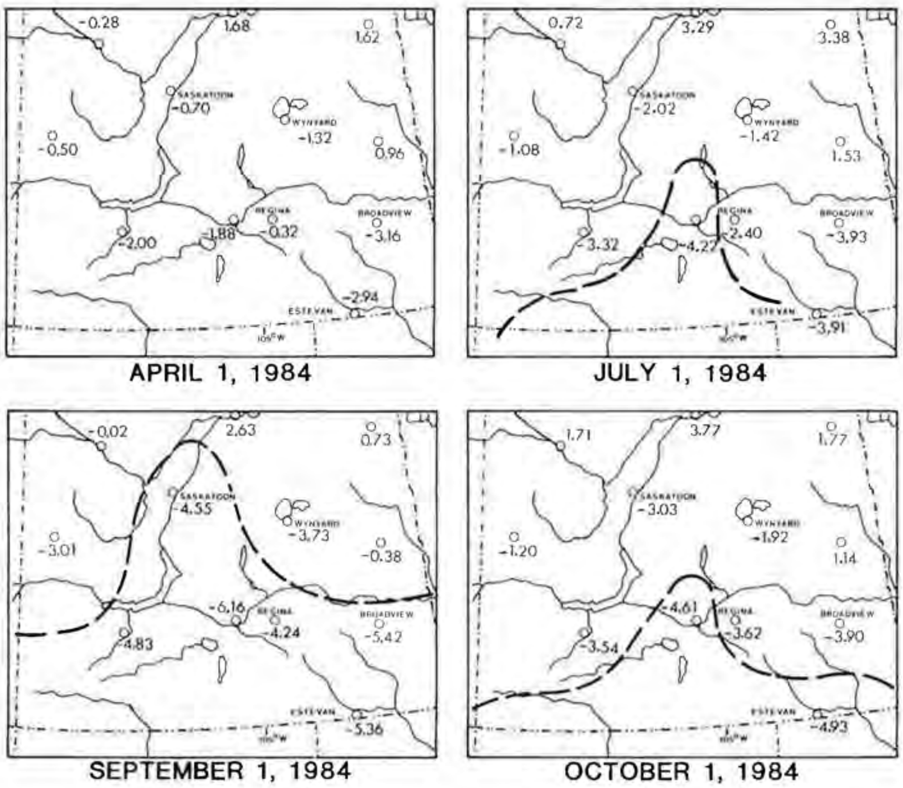
Thus the stage was set for drought before the summer began. Southern Manitoba was in slightly better condition because of timely storms in April. The Prairie Farm Rehabilitation Administration (PFRA) of Agriculture Canada identified all of these problems in its monitoring program for water supply conditions. This program has been effective in maintaining an early warning system for drought. Monitoring is needed to inform policy makers about potential problems so that rational mitigative measures may be implemented.

The dry weather continued through May and June in southern Saskatchewan and Alberta with many areas receiving as little as 50 per cent of the normal rainfall. Dry soils and strong winds were ideal for drifting and blowing dust which were most prevalent in southern Saskatchewan. June is usually the peak rainfall month on the Prairie grasslands so the shortfall was particularly significant. By contrast, the more northerly agricultural regions such as the Hudson Bay area of Saskatchewan had the opposite problem, excessive precipitation. Southern Manitoba, except for the southwest, also received much above normal rainfall in June.

July was extremely dry with as little as 10 per cent of the normal rain in extreme southern Saskatchewan and Alberta and 25 per cent of normal was common elsewhere. Grain kernels shrivelled in the heat and so did farmers' hopes for a decent crop. Most of the meagre rainfall that fell was observed at the end of the month, too late to be useful. A cruel irony was that in the midst of the drought, an area of 2500 square kilometres in southeast Saskatchewan received in excess of 100 mm on the evening of July 30. Pastures and haylands, already in poor condition at the start of the growing season, were desiccated by the heat, sun and wind of July.

August continued hot and dry. At many stations, the mean temperature rivalled that of the record hot August of 1983. Grass fires were reported in several areas of southern Saskatchewan near the end of the month. Lake Diefenbaker failed to fill under the combined influence of low inflow and high evaporation. The summer lake level in 1984 was almost five metres below full storage level, a record low for this reservoir. Many smaller reservoirs in southwest Saskatchewan were extremely low and irrigation was restricted because of a lack of water. However, the dry weather was conducive to good harvesting conditions such that 94 per cent of the wheat harvested in Saskatchewan was expected to fall in the top two grades, much of it with a high protein content (as great as 16 per cent). Crop yields in the drought areas were drastically reduced though.

The cost of the 1984 drought was high. On a provincial basis, the total grain and oil-seed production was 16 and 25 per cent below 1983 levels in Alberta and Saskatchewan, respectively. Thanks to timely June rains, most of Manitoba fared better than its western neighbours, posting an increase in crop production of 11 per cent over 1983, even counting the drought-affected southwest. The loss to livestock producers will continue through the winter as many will have to reduce herd size and import hay and feed from northern areas. Hydroelectric production from Lake Diefenbaker and Tobin Lake in Saskatchewan will be substantially reduced in the coming winter. In Lake Diefenbaker, the volume of water normally available for winter power production is 2.60 million cubic decametres

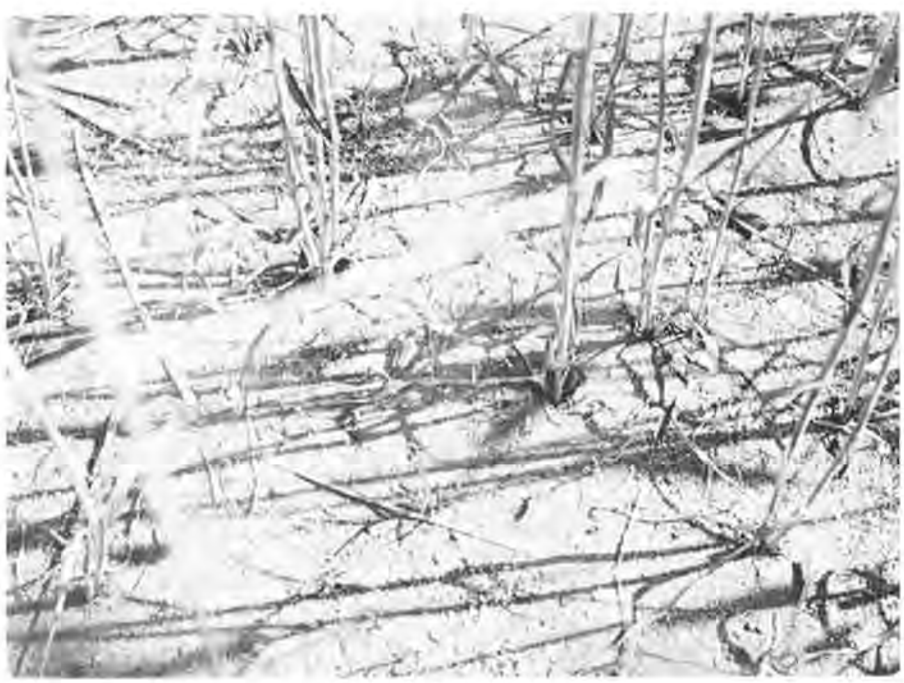


Palmer drought index for stations in southern Saskatchewan. This index uses a soil water budget approach to assess moisture stress (>4: extremely wet; 2 to 4: wet; -2 to $+2$: normal; -4 to -2: dry; and <-4: DROUGHT). The value of -6.16 at Moose Jaw on September 1, 1984 was the most severe monthly value calculated there for the period 1927 to 1984 (Courtesy: K.H. Jones, AES, Regina)

but this year only 0.85 million cubic decametres are available. Waterfowl populations were sharply reduced by the lack of wetland habitat.

Indirect costs will ripple through the Prairie and national economies owing to the lost purchasing power of the farm community. The combination of poor yields and low commodity prices threatens the survival of many farmers, particularly those with high debt burdens.

Autumn rains and snowstorms have brightened prospects for 1985 although much above normal precipitation is needed this winter. On-farm water supplies are poor with dugouts and stock watering reservoirs dry to one-quarter full, so that many farmers are drawing heavily on ground water for stock watering. Irrigation could be curtailed again in 1985 if run-off fails to materialize. Ground water aquifer supplies are dropping and it could take several wet seasons to restore them. The scenes of Ethiopia are not likely to occur on the Canadian Prairies, but another year like 1984 could bring the agricultural economy to its knees.



Thin, drought stressed, and grasshopper-infested spring wheat ripened prematurely by the extreme heat of early August.

Even with modern equipment, new drought resistant varieties of grain, and modern farm practices, the Prairies are still subject to the ravages of drought. The prospect of a warmer but drier climate, as a result of increased carbon dioxide and other radiatively active gases in our atmosphere, poses a challenge to policy makers and planners. Current farm practices such as agricultural drainage of on-farm wetlands may be aggravating the severity of drought. A wise and balanced approach to soil and water management needs to be weighed against ever increasing pressures for increased production. Perhaps the weather of 1984 will be the norm by the middle of the 21st century. If so, the Prairies must adapt or become a desert.

ACKNOWLEDGEMENTS

The author gratefully acknowledges the assistance provided by Ted O'Brien, PFRA - Regina; Fred Luciow, Atmospheric Environment Service (AES) - Winnipeg; Ken Jones, AES - Regina; and Jim Rogers, Inland Waters Directorate - Regina.

Ron Hopkinson is Officer-in-Charge of AES Scientific Services at Regina with responsibility for applications of hydrometeorology to water management in Saskatchewan.

DUSTSTORM!

by Jay Anderson

No feature characterizes the drought years on the Prairies better than the duststorm, and over the years stirring tales of the struggle against wind and dirt have become embedded in western folklore. Most of these stories come from the "Dirty Thirties" when massive storms punctuated the years of drought and depression, adding to the toll of human suffering.

But farming practice and society have changed and drought no longer carries the same burden that it once did. Duststorms too have become less dramatic than 50 years ago, though nearly every dry year still records its days of wind and dirt. Indeed, as lessons learned from the 1930s are forgotten, duststorms may yet rise to plague us once again.

Blowing dust begins as a series of critical events at the interface of air and ground. Close to the surface, within the lowest millimetre or so, wind flow is nearly zero and the force on soil particles is at a minimum. Above this layer for a very short distance, the flow is smooth and *laminar*, and above that, *turbulent*. Initially only soil particles that protrude into the turbulent part of the airstream will be caught up by the wind, provided they are not too large or too firmly attached to other particles. The number of particles that extend into this level is in turn dependent on the depth of the zero velocity layer, which is influenced by the *roughness* of the surface over which the air flows. Surface roughness is a function of the size of the larger particles, soil ridging, vegetation and vegetation residues.

Under normal field conditions, where a mixture of soil particles exist, movement of the most erodable components (about 1 mm in size) begins when the wind speed reaches about 21 km/hour at a height of 30 cm above the ground. Particle motion then falls into one of three categories.

The most critical form of motion is the bouncing or jumping of medium-sized particles along the surface, known as *saltation*. Less important is the rolling of larger particles, called *surface creep*. The third form of motion is *suspension*, in which very fine particles

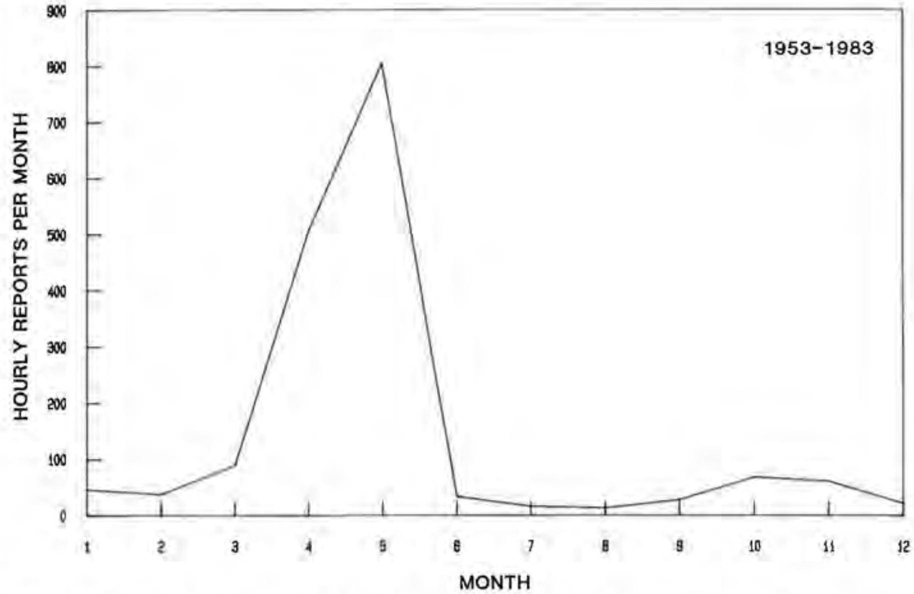


Figure 1a Monthly frequency of blowing dust. This chart shows the number of reports of dust at 5 Prairie stations (Regina, Estevan, Broadview, Brandon and Winnipeg) over a thirty-year period. The peak in the spring occurs when fields are bare for planting; the smaller peak in the fall arises from plowing after harvest. Both seasons are also times for higher wind speeds.

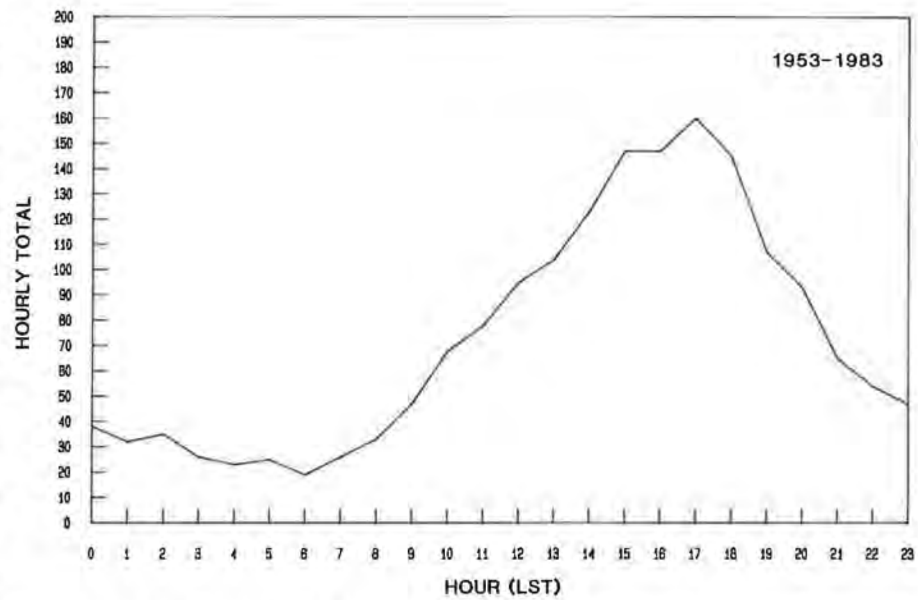


Figure 1b Hourly frequency of blowing dust. This chart shows the number of reports of blowing dust hour-by-hour at 5 Prairie stations (Regina, Estevan, Broadview, Brandon and Winnipeg) over a thirty-year period. The afternoon peak occurs at a time of maximum instability and strongest winds.

dislodged into the turbulent layer by the impact of saltating soil grains are caught up by the wind and remain floating in the air. It is this suspended dust which gives the duststorm its characteristic appearance.

Once soil movement begins, the force of the saltating particles severely abrades the surface, breaking up larger clods and creating more and more particles to be caught up by the wind. In a large field, particles strike the ground many times, setting more and more dust in motion in the downwind direction in a process known as *avalanching*.

Coarse textured soils such as sand, sandy loam and loam are most susceptible to blowing. If the soil surface is crusted, or broken into clods, erosion is inhibited.

Prairie duststorms are a direct result of the agricultural practices of man. In Figure 1a the number of hourly reports of blowing dust at five Prairie stations shows a dramatic peak in October and November during fall plowing. The erosion process began many decades ago with the large-scale destruction of the native grasses and vegetation, and is promoted today by over-tilling of dry soils, which breaks and pulverizes the soil crust.

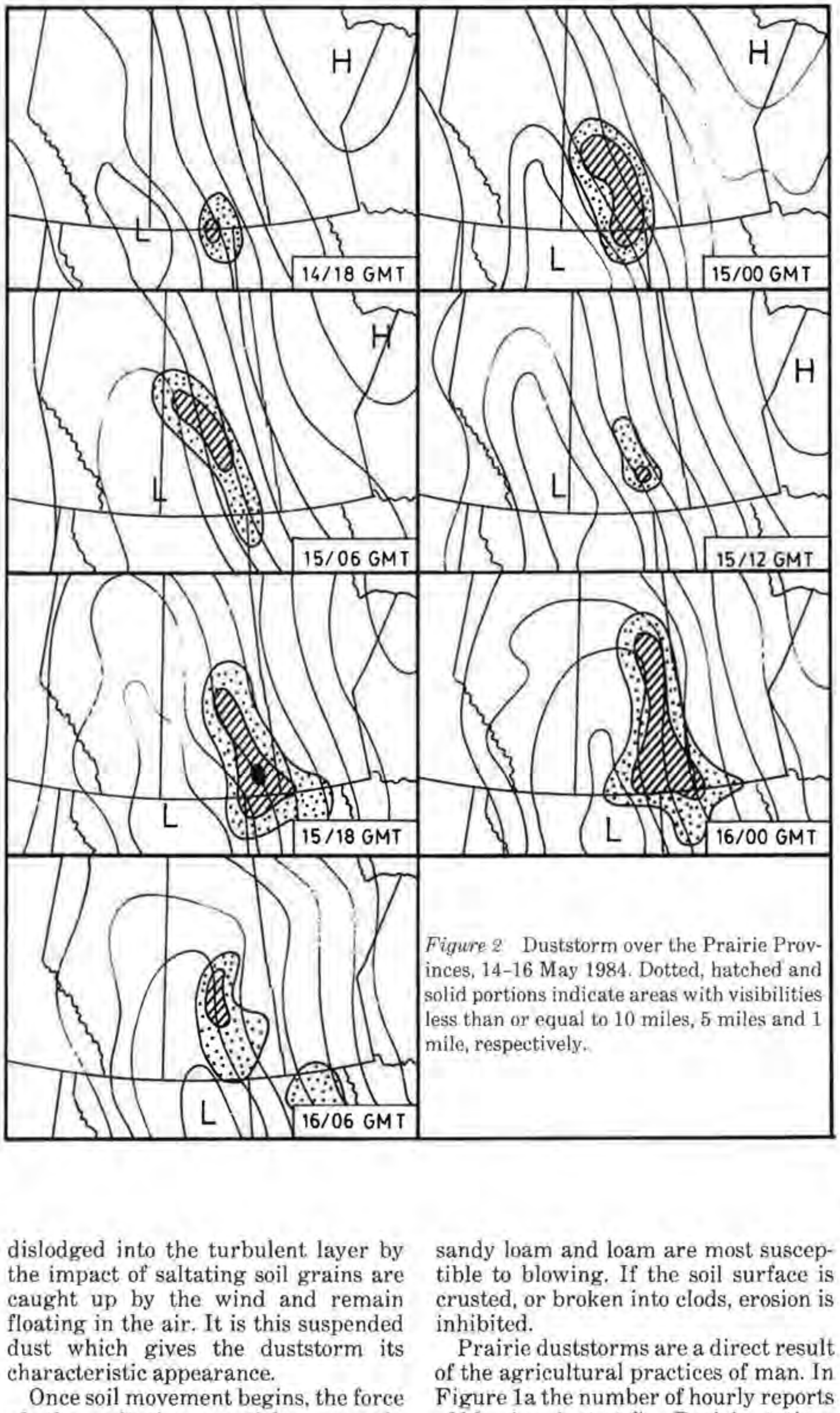


Figure 2 Duststorm over the Prairie Provinces, 14–16 May 1984. Dotted, hatched and solid portions indicate areas with visibilities less than or equal to 10 miles, 5 miles and 1 mile, respectively.

During the 1930s, duststorms were categorized into three types. The *whirlwind* type, caused by thunderstorms and tornadoes, is of small scale and short duration. The *wind-shift* type forms along a sharp low pressure trough, and would probably be called a cold-front storm today. The third type is a straight *windstorm* that develops in the strong pressure gradient associated with an area of high pressure.

A storm of the third type developed over Saskatchewan on May 14 last year and persisted for several days. Figure 2 shows the evolution of this storm over a 36-hour period and illustrates a number of typical characteristics. The storm began on the morning of the 14th in an area of sandy and sandy-loam soils straddling the international border. This region had been slightly deficient in winter precipitation, but had only accumulated 25 to 50 per cent of normal rainfall in the six weeks prior to the storm.

The area of dust grew through the afternoon of the 14th (15/00 GMT) as wind strengths increased and atmospheric stability decreased. Considerable dustiness persisted past midnight (15/06 GMT), but by morning lighter surface winds and a weak nocturnal inversion had considerably reduced the area affected.

The return of daylight and the ensuing breakdown of the inversion, along with continued strong winds, revived the storm on the 15th. By noon (15/18 GMT) visibilities were falling below 1 km over parts of southeast Saskatchewan, and the dust had reached more than 3 km up into the air. Satellite pictures (e.g., Figure 3) showed a greyish pall over the area, scattering the rays of the setting sun.

By late in the day the area of strongest winds had moved into Manitoba where fields and soil were not so favourable to blowing. Even so the storm continued for another day at reduced intensity.

The diurnal growth and decay of a duststorm is also mirrored in Figure 1b, which shows the hourly incidence of blowing dust at a number of Saskatchewan and Manitoba locations. Reports of blowing dust are most common late in the afternoon when the heating of the earth's surface brings greatest instability, and the mixing of the atmosphere through a large depth brings stronger winds from aloft down to the surface. Conversely, the lowest frequency of dust reports comes when the temperature bottoms out just before sunrise.

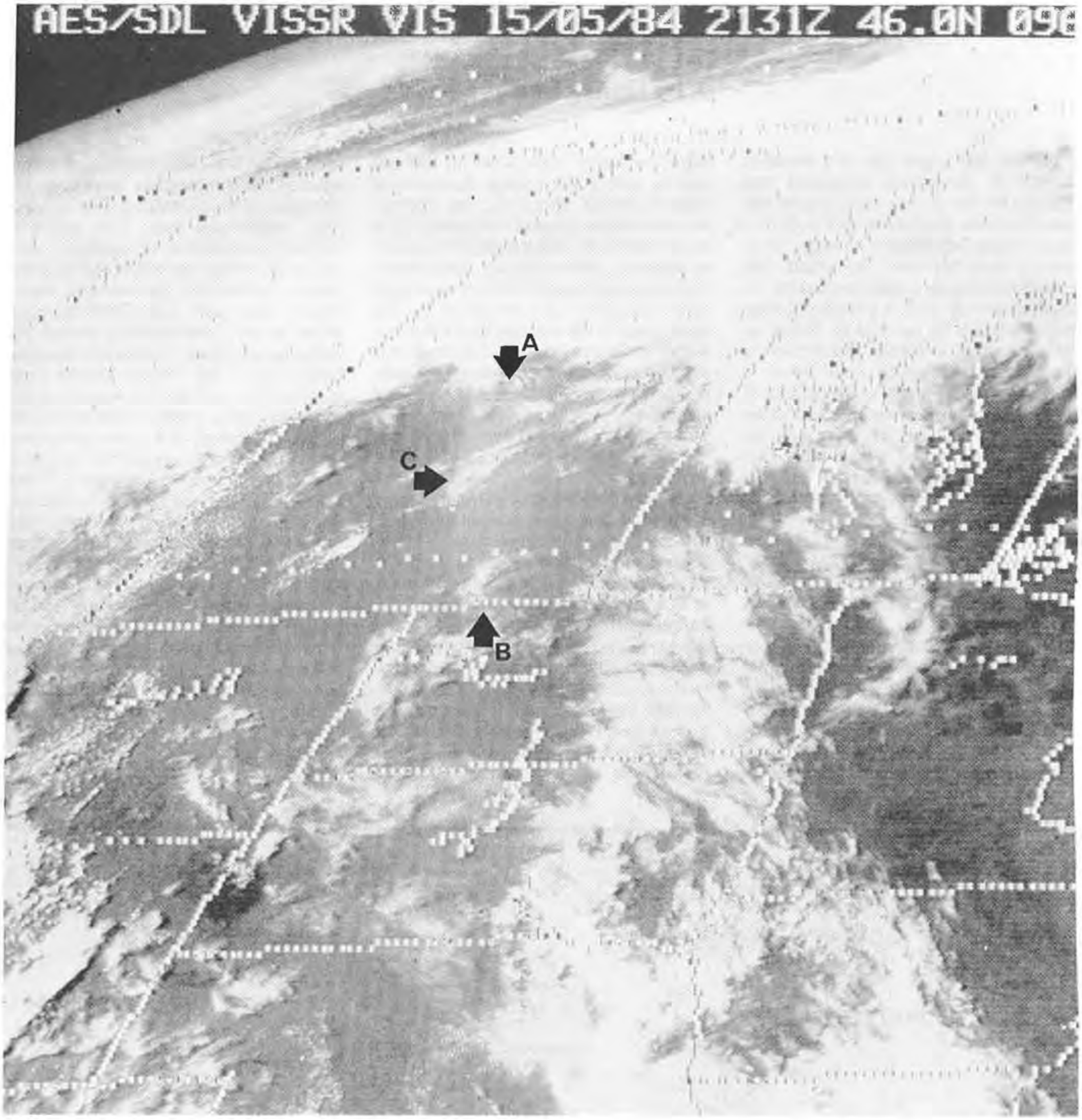


Figure 3 The area of dust is faintly visible between arrows A and B. The trailing edge is more clearly defined (C). The satellite visual image was taken on May 15, 1984, around mid-afternoon local time.

Prairie duststorms are not a relic of the past, but an ongoing phenomenon since intensive cultivation aggravates the effects of dry weather. Nevertheless there is a widespread realization that control measures are essential if damage to the land and soil fertility is to be prevented. Blowing and drifting can be controlled by appropriate plowing techniques that promote the formation of large clumps, by windbreaks, by farming in narrow strips to control avalanching, and by leaving stubble to bind and roughen the soil. As these practices are continued, duststorms may someday be no more than a folk-tale.

Jay Anderson is a meteorologist at the Prairie Weather Centre in Winnipeg, Manitoba. Mr. Anderson has been involved with the applications of satellites to weather forecasting.

CARBON DIOXIDE AND CLIMATE CHANGE

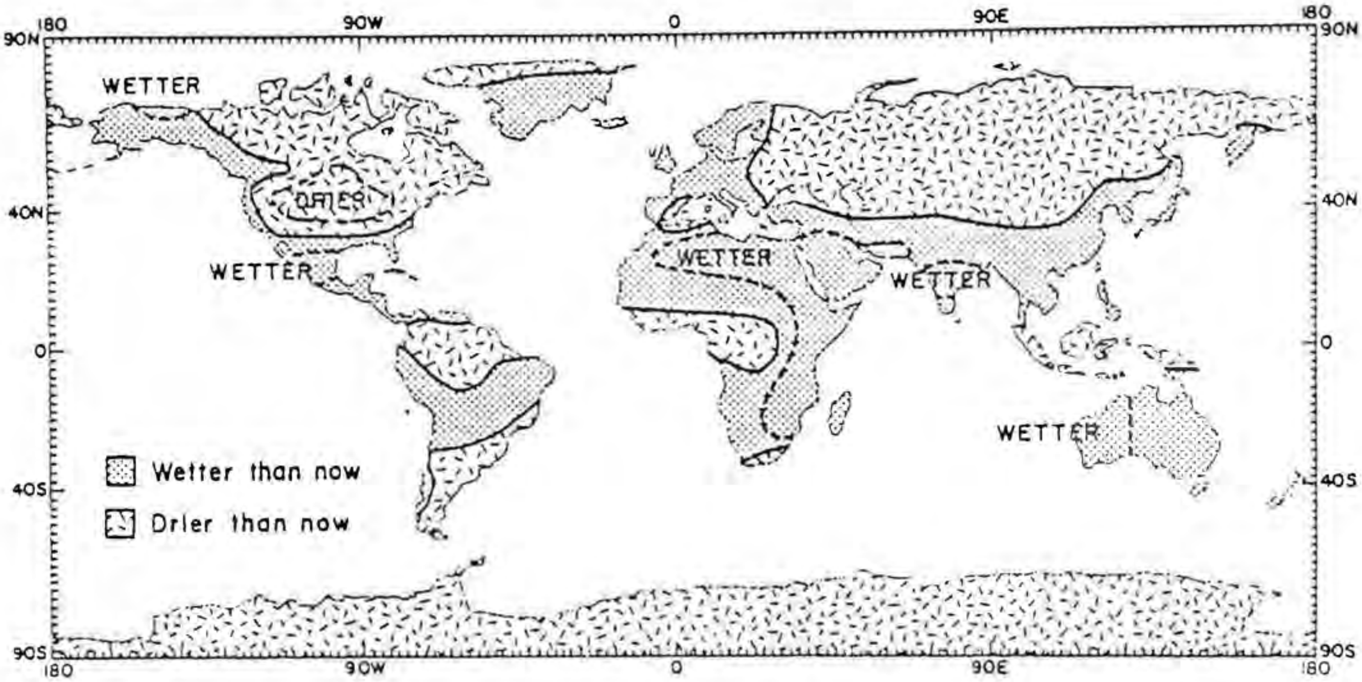
by Henry G. Hengeveld

Almost 100 years ago the Swedish chemist S. Arrhenius suggested that changes in the atmospheric concentration of carbon dioxide might well be a major cause of climate change. However, it was not until the 1960s that scientists seriously began to consider the possibility that such a climate change might already be occurring. Today, as the scientific evidence continues to mount, an increasing realization is emerging that man is significantly altering the chemical composition of his atmosphere and that the effects of this as yet uncontrolled experiment are likely to change the earth's climate system beyond anything experienced throughout the history of human civilization.

There are good grounds for concern. Continuous measurements of atmospheric carbon dioxide concentrations, initiated at Mauna Loa, Hawaii in 1958, reveal an unmistakable, world-wide rise in concentration levels that is both quite rapid and escalating. Concentrations are presently rising at a rate of 3-4% per decade and are believed to have already increased by 25% over the past 100 years. The primary cause of this increase is the rapid escalation in the use of oil, gas and coal to satisfy the energy demands of today's society. Presently, the energy-related consumption of these fossil fuels emits close to 6 billion tonnes of carbon, as gaseous carbon dioxide, into the atmosphere each year. While a portion of these emissions are removed by the oceans and land vegetation, 50-60% remains in the atmosphere. Although it is difficult to predict future energy trends, it now appears likely that the level of atmospheric carbon dioxide concentration will have doubled over that of pre-industrial periods by the end of the 21st century.

Carbon dioxide alters the heat balance of the earth through a process commonly referred to as the "greenhouse effect". This gas is relatively transparent to solar radiation entering the atmosphere at short wavelengths, mostly in the visible range, thus allowing the sun to warm the earth's ocean and land surfaces. On the other hand, longer wavelength infrared radiation emitted from the earth's surface towards space is partially absorbed and re-radiated by the carbon dioxide molecules, thus "trapping" additional heat in the lower atmosphere. Increasing the concentration of atmospheric carbon dioxide improves the efficiency of the climate system in "trapping" additional heat. This effect is further complicated by feedback processes involving various climatic parameters, particularly sea ice, snow, water vapour and cloud cover. Intricate computer models developed in recent decades by scientists to simulate the total behaviour of the climate system have been used to estimate the heating effect of atmospheric carbon dioxide. These models, although still quite primitive, indicate that average world temperatures could increase between 1.5 and 4.5°C if the carbon dioxide concentration were doubled. Furthermore, they indicate that warming in Arctic regions would be 2-3 times greater, with most significant changes occurring in winter.

Carbon dioxide is not the only "greenhouse" gas that is causing concern. Other minor atmospheric gases, such as methane, freons and oxides of nitrogen, have effects similar to that of carbon dioxide and are also increasing in concentration. These gases could add up to as much as 50% to the effect of carbon dioxide.

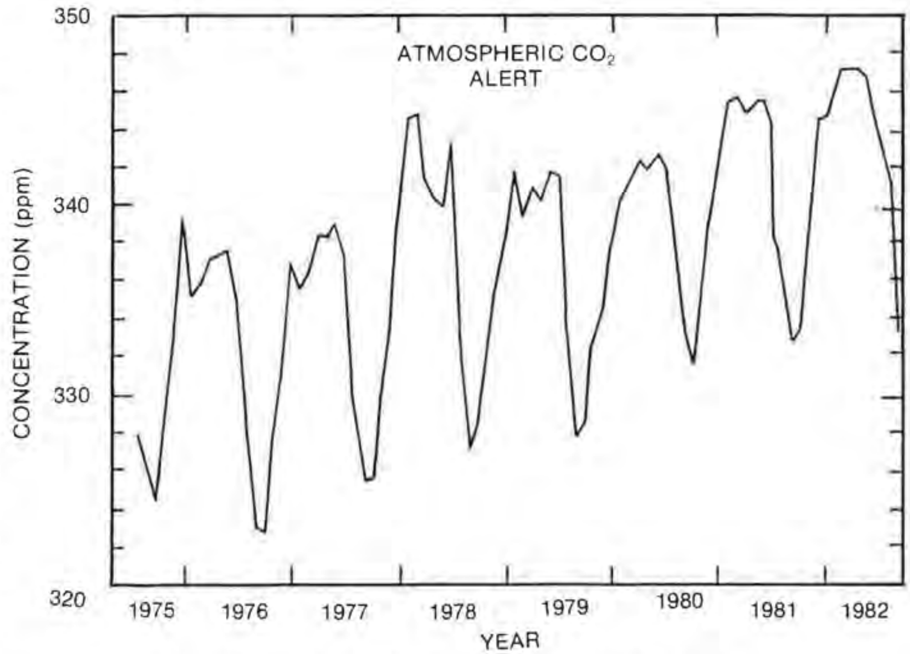


Possible global soil moisture changes for $2 \times CO_2$ environments, based on paleoclimate, historical and climate model studies (W.W. Kellogg and R. Schware in *Climate Change and Society*, Westview Press, 1981).

Although the timing and magnitude of global temperature changes due to increasing carbon dioxide is still actively debated, scientists generally agree that a carbon dioxide induced warming would likely exceed anything that has occurred in the past 10,000 years and possibly the last 2 million years. Significant alterations in the global wind patterns and hence in the precipitation regimes would result. Tentative scenarios developed by computer models indicate a generally increased aridity for mid-northern latitudes between 35 and 52°N, and increased soil moisture for tropical and Arctic regions. Data from studies of warm climates in past eras tend to support these results. Glaciologists also indicate that the disintegration of the west Antarctic ice-cap could eventually occur, resulting in global sea level rises of 5–7 m and extensive coastal flooding. However, such an event would probably take several centuries to occur.

A carbon dioxide induced climate change would have significant impacts on the global community. Some nations would win, others would lose. The same holds true for regions within each nation. Canada, being particularly sensitive to temperature change, would be among the most significantly affected countries in the world. The impacts would be substantial. Some would be benign, others costly. These include: longer and warmer growing seasons, enhancing vegetative growth; drier soil conditions in most agricultural regions, likely exceeding the drought conditions of the 1930s; improved shipping in ice-congested waters; lower water quantity and quality in the Great Lakes; lower energy demands for space heating; greater threat of forest fires and insect infestation; and longer recreational seasons in summer but shorter, in winter. Canada's economic and political well-being will also be dependent on the impact on other countries.

There are, of course, other climatic forces at work that affect our climatic system which could enhance or counteract the carbon dioxide induced effects. Prominent among these are the cooling effects of volcanic dust and gases, the cyclic warming and cooling effects of variations in solar radiation, and the longer term effects of changes in the earth's orbital patterns. Present calculations indicate, however, that at least for the next few centuries these other forces will have a climatic effect an order of magnitude smaller than that of carbon dioxide and would thus tend to modulate the general trend of a carbon dioxide induced global warming. These calculations may be wrong or other possible counter-balancing forces may have been overlooked. It is unlikely we will know for sure until the first unmistakably carbon dioxide induced climate change is detected. That could be within the next one or two decades. Meanwhile we must endeavour to improve our understanding of our climate, watch carefully for possible changes and prepare ourselves to respond if and when necessary.



Monthly atmospheric CO_2 concentration trend at Alert, NWT.

Emissions from industrial regions are responsible to a large extent for the continued increase of CO_2 concentration levels in the atmosphere.

Mr. Hengeveld is an Advisor to the Canadian Climate Centre in Toronto on carbon dioxide related matters including climate change. His article is reprinted from *Climatic Perspectives* Vol. 5, July 1983 Monthly Supplement, published by the Atmospheric Environment Service.

CANADIAN WEATHER EXTREMES

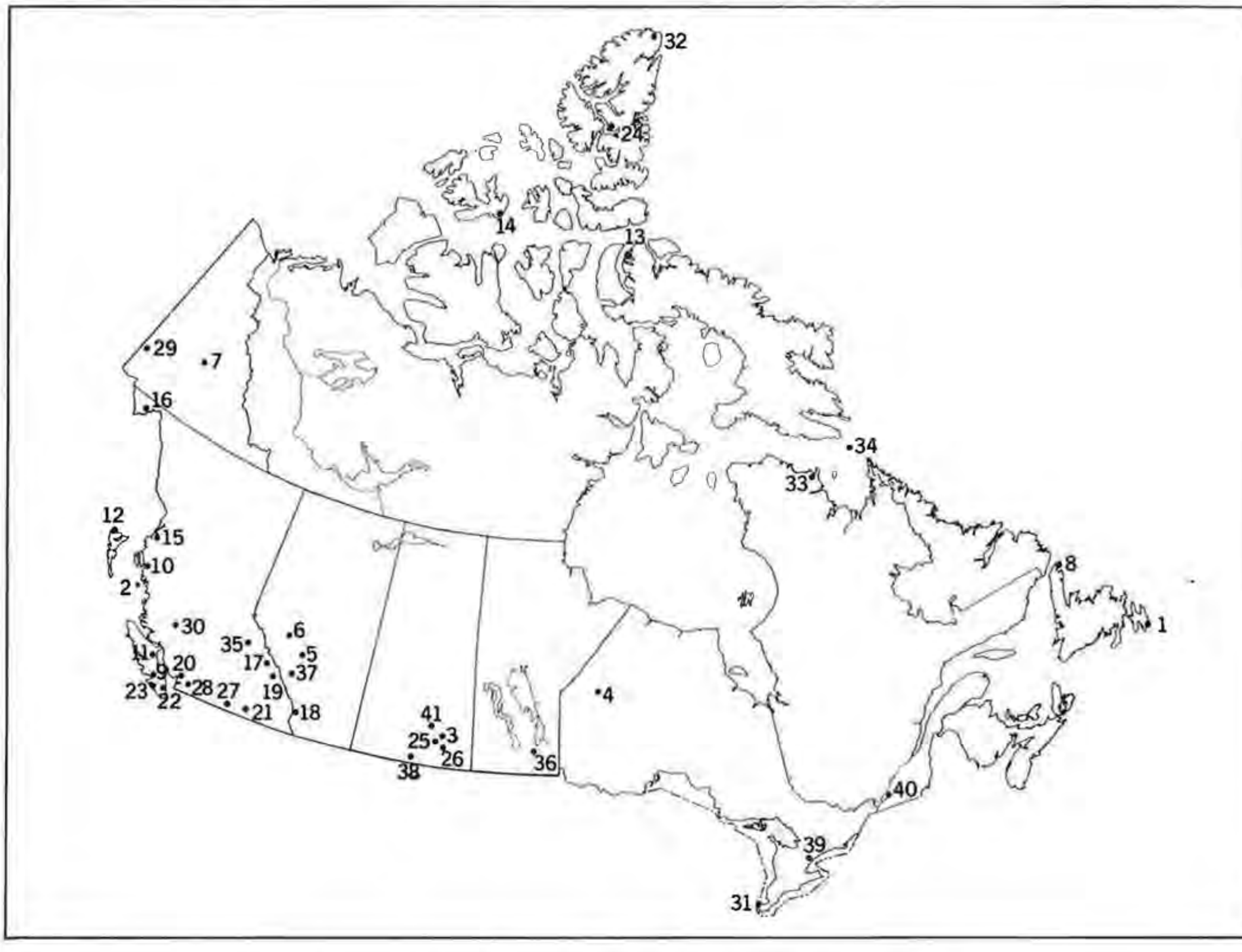
by Michael Newark

How violent can the weather be? How hot or cold or windy? What extremes limit the natural range of the weather elements? The answers to such questions serve more purposes than just satisfying mere curiosity. How, for example, can engineers design efficient and cost-effective drainage systems if they don't know what volumes of water to expect? How can they design roofs strong enough to bear the weight of snow, or structures strong enough to withstand the force of the wind, or buildings warm or cool enough to shelter us from the temperature extremes of our fickle atmospheric environment? How can we assess and plan for the potential impact of changes in the climate upon our agricultural and forest industries if we do not already know the extremes that regulate these activities?

Quite obviously, weather data must be analysed in a number of complex ways in order to provide useful information for such purposes, but in any examination of extremes, absolute upper and lower limits can always be found. The magnitudes of these limits depend upon such factors as location; the period of time under investigation (clearly the atmosphere had different limits during the ice-ages than it has now); and the length of the period. The reason is that weather extremes are somewhat like the records set by athletes: the more time that passes, the more likely it is that the records will be broken.

Anyway, for the reader who is curious about such things, we present the absolute limits of weather behaviour observed within the geographical confines of Canada during the past eighty years.

Michael Newark is founder of *Chinook* and served as Editor from 1978 to 1984. Currently he is a meteorologist developing long-range climate forecasting techniques in the Canadian Climate Centre at Toronto.



Location of places referenced in the tables of Canadian weather extremes.

Element/Extreme	Place and Map Reference Number		Date or Period	Record
FOG - Most				
Greatest mean annual number of days	Cape Race, Nfld.	(1)		158 days
FROST				
Longest frost-free period	McInnes Island, B.C.	(2)	Mar. 5, 1957 - Nov. 15, 1958	618 days
HAIL - Worst				
Heaviest hailstone (verified)	Near Cedoux, Sask.	(3)	Aug. 27, 1973	Weight 290 g, diameter 102 mm
Largest diameter hailstone (unverified)	Windigo Lake, Ont.	(4)	Aug. 23, 1948	Weight 255 g, diameter 127 mm
Greatest mean annual number of hail days	Edson and Red Deer, Alta.	(5, 6)	7 days	
PRESSURE				
Maximum*	Mayo Airport, Yukon	(7)	Jan. 1, 1974	106.76 kPa
Minimum	St. Anthony, Nfld.	(8)	Jan. 20, 1977	94.02 kPa
RAINFALL - Wettest				
Greatest in 24 hours	Ucluelet Brynnar Mines, B.C.	(9)	Oct. 6, 1967	489.2 mm
Greatest in 1 month*	Swanson Bay, B.C.	(10)	Nov. 1917	2235.5 mm
Greatest in 1 year	Henderson Lake, B.C.	(11)	1931	8122.4 mm
Greatest mean annual	Henderson Lake, B.C.	(11)		6477 mm
Most days with rain (on average in year)	Langara, B.C.	(12)		242 days
RAINFALL - Dryest				
Minimum in 1 year	Arctic Bay, N.W.T.	(13)	1949	12.7 mm
Least days with rain (on average in year)	Rea Point, N.W.T.	(14)		8 days
SNOWFALL - Heaviest				
Greatest in 24 hours	Lakelse Lake, B.C.	(15)	Jan. 17, 1974	118.1 cm
Greatest in 1 month	Haines Apps No. 2, B.C.	(16)	Dec. 1959	535.9 cm
Greatest in 1 winter	Revelstoke Mt. Copeland, B.C.	(17)	1971–1972	2446.5 cm
Greatest in 1 summer	Livingston R.S., Alta.	(18)	June 1963	164.5 cm
Greatest mean annual	Glacier NP, Mt. Fidelity, B.C.	(19)		1433.0 cm
Greatest depth on ground	Loch Lomond, B.C.	(20)	Apr. 1, 1946	775 cm
Most days with snow (on average in year)	Old Glory Mountain, B.C.	(21)		142 days
SNOWFALL - Lightest				
Lowest mean annual	William Head, B.C.	(22)		17.2 cm
Least days with snow (on average in year)	William Head, B.C. and Carnaval Point, B.C.	(22) (23)		3 days
SUNSHINE				
Greatest monthly	Eureka, N.W.T.	(24)	May 1973	621 hours (83% of total possible)
TEMPERATURE - Hottest				
Extreme maximum	Midale and Yellow Grass, Sask.	(25) (26)	July 5, 1937	45°C
Highest mean annual maximum	Osoyoos West, B.C.	(27)		15.9°C
Highest mean daily	Sumas Canal, B.C.	(28)		10.7°C
TEMPERATURE - Coldest				
Extreme minimum*	Snag, Yukon	(29)	Feb. 3, 1947	-63°C
Highest mean annual minimum	Eureka, N.W.T.	(24)		-23°C
Lowest mean daily	Eureka, N.W.T.	(24)		-19.7°C
TEMPERATURE - Greatest Range				
Mean annual	Puntzi Mountain, B.C.	(30)		15.8°C
Between mean extremes of maximum and minimum	Mayo Airport, Yukon	(7)		98.3°C
THUNDERSTORMS				
Greatest mean annual number of thunderstorm days	Windsor, Ont.	(31)		34 days
Lowest mean annual	Eureka and Alert, N.W.T.	(24) (32)		0
WIND - Strongest				
Highest hourly speed	Cape Hopes Advance, Qué.	(33)	Nov. 18, 1931	201.6 km/h
Highest mean annual speed	Resolution Island, N.W.T.	(34)		35.3 km/h
WIND - Weakest				
Lowest mean annual speed	Blue River Airport, B.C.	(35)		3.5 km/h

*Also a North American record.

Note: The highest wind gust speeds in Canada are not known, but are estimated to lie within the range from 330 to 415 km/h in severe tornadoes.

By general consensus, the following events are considered to be the most extreme of their kind in Canada. (Note that the damage amounts are given in dollar values valid for the particular year.)

Most Devastating Event	Place and Map Reference Number		Date or Period	Impact
DROUGHT AND HEAT	Western Canada		1936-1937	more than 600 deaths
FLOOD (Red River)	Winnipeg, Man.	(36)	May 1950	more than $100 million damage
HAILSTORM				
Damage	Calgary, Alta.	(37)	July 28, 1981	$100 million damage
Deaths	Constance, Sask.	(38)	July 15, 1928	750 sheep and 3 horses killed
HURRICANE (Hazel)	Toronto, Ont.	(39)	Oct. 15-16, 1954	80 killed, $25 million damage
ICE STORM	Montréal, Qué.	(40)	Feb. 25-26, 1961	$7 million damage
TORNADO	Regina, Sask.	(41)	June 30, 1912	28 killed, 300 injured, 2500 homeless, $4 million damage
LIGHTNING	Touchwood Hills (near present day Regina, Sask.)	(41)	Summer, 1863	30 to 400 indians killed in quick succession

Extremes of cold can create nature's scenic masterpieces, but may also slacken the flow of water needed for hydroelectric power generation.

ACID RAIN AND SNOW AT KEJIMKUJIK, NOVA SCOTIA

by Billie L. Taylor

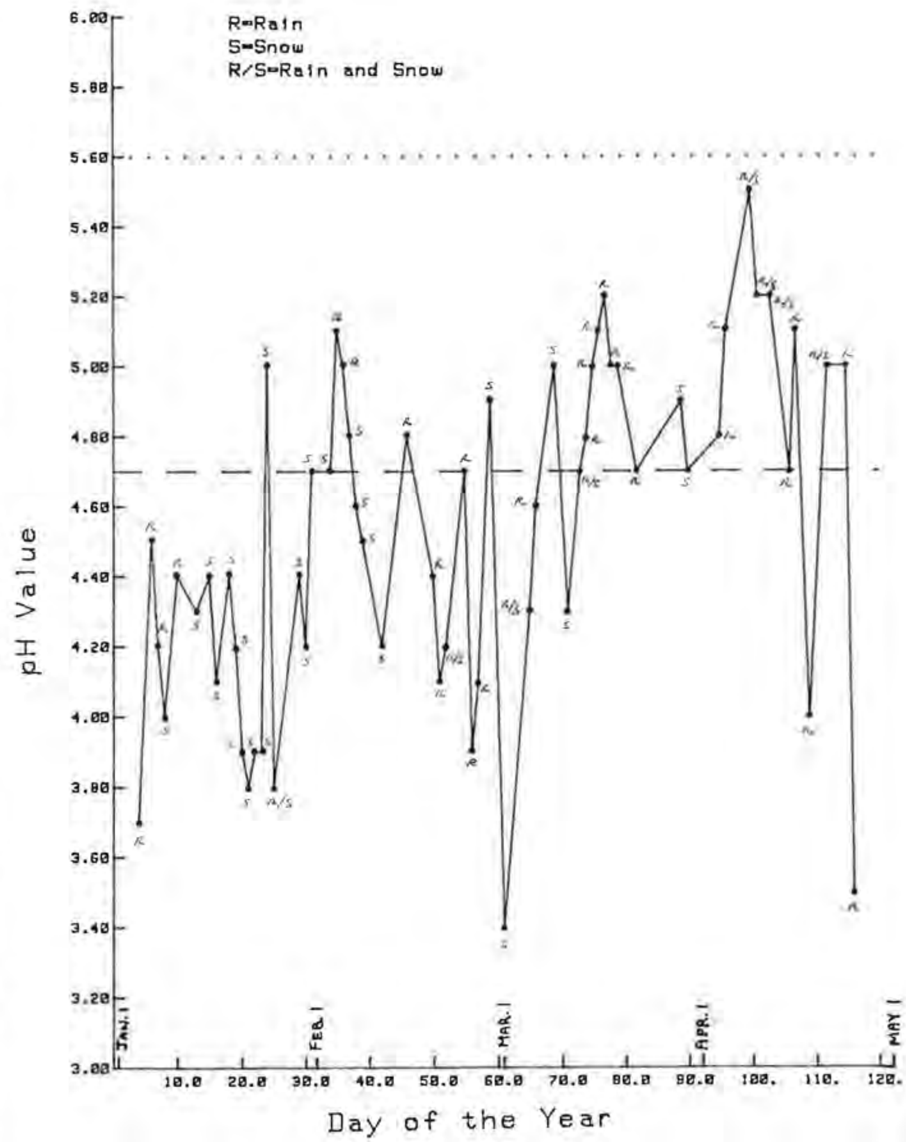
The Atmospheric Environment Service has operated a daily precipitation sampling station in Kejimkujik National Park in southwestern Nova Scotia since May 1979. Daily precipitation samples are taken at the station and analysed for pH and the concentrations of such chemical constituents as sulphates and nitrates.

The pH value is a measure of the acidity of the precipitation. The pH scale ranges from 0 (maximum acidity) to 14 (alkaline). A pH value of 7 is neutral. The scale is logarithmic with a ten-fold difference between integers; for example, a pH of 5 is ten times more acidic than a pH of 6.

Clean precipitation, which is not contaminated by pollutants, is slightly acidic with a pH of about 5.6. Most of eastern Canada receives acid precipitation with average pH values between 4.2 and 4.5.

Environmental damage to lakes and streams is usually observed in acid sensitive areas that regularly receive precipitation with pH values less than 4.7. Readings of 4.2 and below, for rain or snow, are considered strongly acidic and are not uncommon at Kejimkujik. The effects of acid rain and snow are generally cumulative over time, although fish kills have been observed after low-pH rain events.

The pH values of rain and snow at Kejimkujik for the first four months of 1984 are plotted in the accompanying graph. All precipitation events over that period were more acidic than clean precipitation, and more than half the events were more acidic than pH 4.7. Strongly acidic events, with a pH of 4.2 or less, occurred almost one third of the time and were especially common in January and February. Most of these strongly acidic events had picked up acidifying pollutants from the U.S. Midwest, the U.S. Eastern Seaboard, Ontario or southern Québec. The air that produced the cleaner precipitation events came from unpolluted areas, such as the Atlantic Ocean, northern Québec, Labrador and Newfoundland.



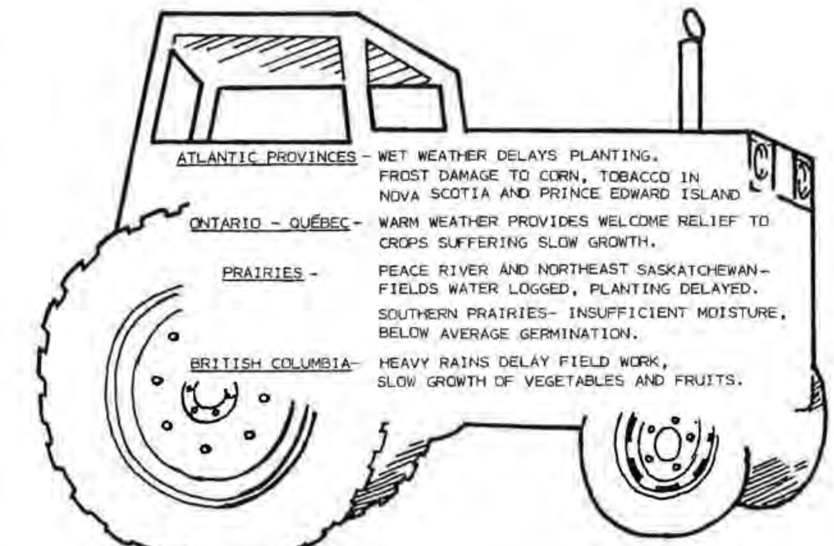
The pH of precipitation observed at Kejimkujik, N.S., January–April 1984.

Ms. Billie Taylor is a meteorologist with Scientific Services of the Atmospheric Environment Service at Halifax, N.S., engaged in environmental studies of the Atlantic Region.

CANADIAN WEATHER REVIEW: SUMMER 1984

by Morley Thomas

Summer, the calendar months of June, July and August, is the season most Canadians of all ages look forward to. There are, of course, winter enthusiasts, but good summer weather means a productive agricultural season in rural Canada and a week or two of ideal vacation weather in urban Canada. There was enjoyable vacation weather across southern Canada during the summer. However, the most important socio-economic climatic impact was the continued hot, dry weather in western Canada that led to drought-like conditions unsurpassed since the 1930s.



The agricultural situation across Canada in early June 1984.

DROUGHT

As early as mid-April, concern was expressed about the inadequate soil moisture reserves, and low water supplies in ponds and wells across the southern Prairies. By mid-July, government hydrologists were claiming that the area south of a line from Calgary through Saskatoon to Brandon was experiencing the poorest growing season since the Dirty Thirties. It was speculated that nearly 50% of the grain crops in southern Alberta and southern Saskatchewan had been killed and a severe grasshopper infestation was under way. Hot and dry conditions continued throughout August in most of the drought-stricken area but in mid-September, a Statistics Canada survey revealed that although the mid-summer drought had shrivelled the crops, western grain growers were harvesting a very high quality crop.

The worst drought damage occurred in southern Alberta, southern Saskatchewan and southwestern Manitoba but growing conditions were better than usual in central Manitoba. Consequently, wheat production rose by about 8% in Manitoba in 1984 but fell by 28% in Alberta and 25% in Saskatchewan, production figures higher than those estimated earlier in the year. The total Prairie wheat production was estimated at 20,000,000 tonnes, about 78% of the 1984 crop. In other wheat exporting nations, production is estimated to be up, for example, 6% in the United States and 22% in the European Economic Community above last year's. However, wheat production in Australia dropped 24% and in Argentina 19% below last year's.

YUKON TERRITORY

Cool, damp weather prevailed in the Yukon during June until late in July. Below-freezing temperatures were reported at Whitehorse as late as July 19, but were followed by record-breaking warmth later in July and early in August. On August 4, Whitehorse reported a temperature of 30.2°C, the highest August temperature ever recorded there. Summer was short-lived, however, as cool, Arctic air moved over the territory later in the month establishing record low daytime readings for five consecutive days. Snow fell and deep snow-drifts closed the Taylor Highway between Dawson and Alaska.

NORTHWEST TERRITORIES

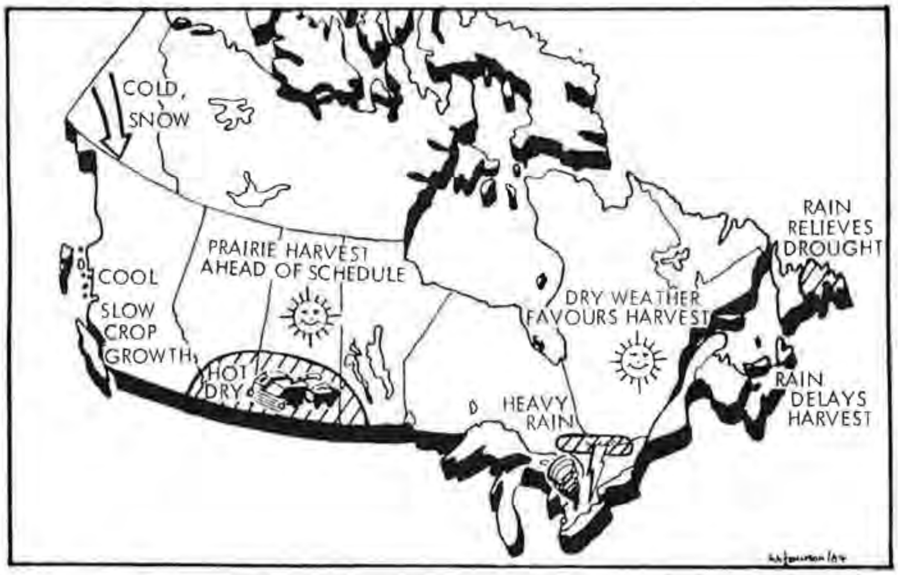
During June and the first half of July, relatively warm temperatures covered the Northwest Territories. Then, during the last two weeks in July, abnormally cold conditions in the western Arctic were balanced by abnormally warm conditions in the eastern Arctic. This contrast was reversed during the first two weeks in August when warm conditions were reported in the District of Mackenzie in contrast to the colder than normal conditions in the District of Franklin. During the first week of August, temperatures were as high as 35°C at Fort Simpson but were below freezing on Baffin Island. Precipitation patterns were quite variable; Yellowknife had the wettest summer in ten years.

BRITISH COLUMBIA

June was a disappointing month for early vacationers in British Columbia when cloudy, cool and rainy conditions prevailed. This weather also hampered farming and retarded the crop season noticeably. In the south, the weather improved in July, but remained fairly cool and became dry in the interior. Conditions were unsettled in the north in July and again late in August, and heavy thunderstorms occurred in the south in August. July was entirely dry at Victoria with more than 400 hours of bright sunshine. Forest fires in the north were started by lightning, but the following cool, wet weather helped keep them under control.

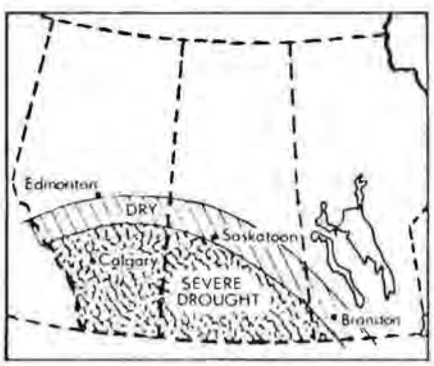
PRAIRIE PROVINCES

The southern portions of the Prairie Provinces experienced droughty conditions unequalled for many years. It was the driest summer in 17 years across most of southern Saskatchewan and portions of the other two provinces. At Lethbridge it was the driest summer in 35 years, and at The Pas, Manitoba the warmest in at least 41 years. Along with the drought, several violent storms struck localities mainly in Saskatchewan and Manitoba. In southern Mani-



The agricultural situation across Canada in late August 1984.

toba heavy thunderstorms were reported on June 15 and 16 and tornadoes on June 21 and 22. On June 29, several thunderstorms were reported in central Alberta. Outside of the drought area, Winnipeg reported its second wettest month on record with 228 mm of rain in June.



Worst drought in over 90 years on the southern Prairies.

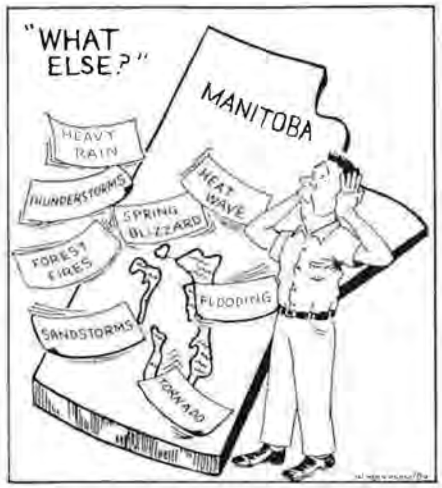
By the end of July, many areas of southern Saskatchewan reported less than 50% of normal rainfall over the growing season period beginning April 1. Lethbridge had 36 consecutive days without any measurable rain and North Battleford received a July total of 11.4 mm, the lowest ever in that month since records began. It was hot towards the end of July when several stations reported daytime maximum temperatures of 38°C. Hot, dry conditions continued in August establishing numerous maximum temperature records. The extreme heat and scanty rainfall fostered a serious grasshopper infestation in southern Saskatchewan and southern Alberta and large grassland fires during the latter part of August. The warm, dry weather, however, hastened harvest work across the Prairies and the cutting and swathing work was finished two to three weeks ahead of normal in some areas.

ONTARIO

Near-normal temperatures prevailed during the summer, although in the south particularly warm periods were experienced in early June and again in August. Daytime temperatures rose above 30°C at many locations making mid-August especially warm. Across much of northern Ontario, the summer was the wettest in 16 years. The south experienced the usual number of isolated, heavy thunderstorms, and tornadoes were reported in eastern Ontario in June and July and in southwestern Ontario and at Toronto in mid-August. Rainfall was exceedingly variable across the south with St. Catharines reporting only 29 mm in July, and Kingston a record amount, 194 mm, in August.

QUÉBEC

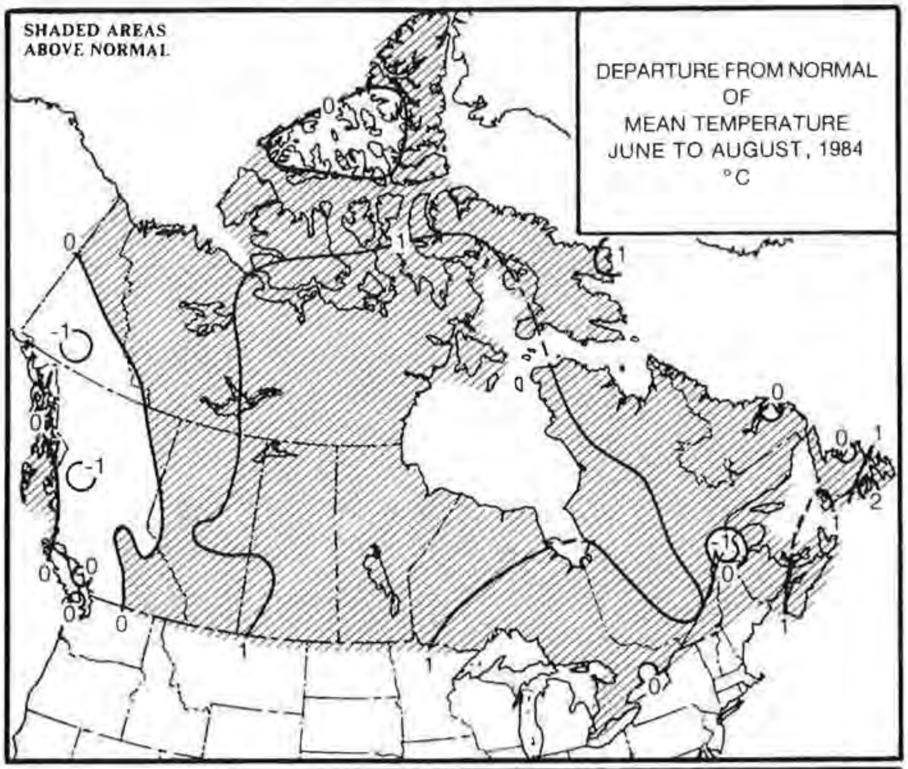
In June, pleasant, dry weather prevailed over western Québec although the month was cool and wet in the eastern part. Temperatures were near-normal across the province in July but were warm in August. June rainfall was generally near-normal but July was dry in western Québec with heavy downpours in the Trois Rivières, Sherbrooke, Québec portion. The situation was reversed in August; the Ottawa Valley received excessive amounts and central Québec very little. Tornadoes struck in the Ottawa Valley on July 15 causing loss of life and many injuries.

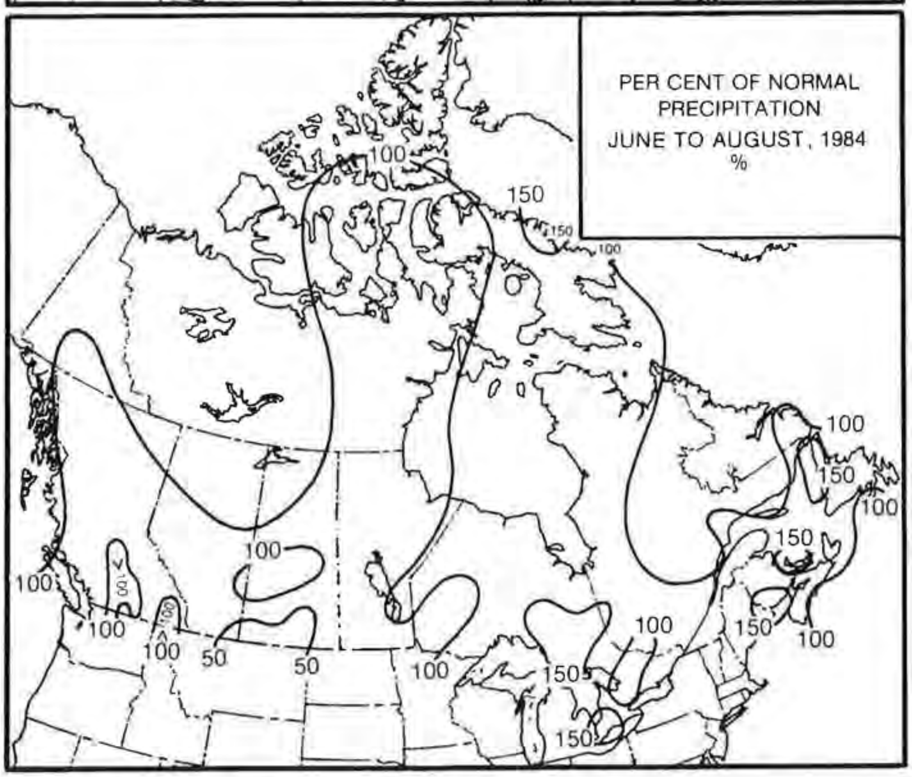


Violent storms lash southern Manitoba in late June.

ATLANTIC PROVINCES

Cool weather with excessive precipitation predominated throughout the Atlantic Provinces in June except for a warm, dry spell from the 9th to the 13th during the visit of the Tall Ships to that region. Frost during the third week of June damaged the corn and tobacco crops. Better sunny and warm weather was experienced during July - in Halifax it was the warmest July since 1961. During the last week of the month, a heat wave covered the Maritimes with daytime temperatures in the low 30s. Precipitation was generally below normal in July but August was warm, dull, and oppressively humid. Precipitation was spotty and generally below normal in New Brunswick although 173 mm was reported at Charlottetown in July. Most of the precipitation occurred in the latter half of August ending the drought-like conditions that had prevailed in some parts of the Atlantic Provinces during July and early August. The warm conditions, however, contributed to one of the best corn crops in Nova Scotia's history.





ACKNOWLEDGEMENTS

Extensive use was made of *Climatic Perspectives*, Vol. 6, Nos. 22-35 in preparing this article; A. Shabbar's summer temperature and precipitation maps have been reproduced as well as several of W. Johnson's drawings. *Climatic Perspectives* is an AES periodical prepared in the Canadian Climate Centre and edited by A. Shabbar.

Morley Thomas has had a long and distinguished career with the Atmospheric Environment Service and the World Meteorological Organization. He is a former Director General of the AES Canadian Climate Centre and is currently Archivist for the Canadian Meteorological and Oceanographic Society.

NEWS AND NOTES

First International Conference on School and Popular Meteorological Education

This past July an international gathering, concerned about the state of school and popular meteorological education, took place at Oxford University, England. This first conference was sponsored by the Royal and American Meteorological Societies, with support and assistance from the World Meteorological Organization. More than eighty representatives from twenty-five countries, shared their involvement with educational activities. Speakers from a variety of backgrounds also shared their concerns for a need to increase the awareness of the overall importance of the role that meteorological education can play in the amelioration of science education in general.

A statement was issued by the conference calling for action by governmental agencies, professional societies, other organizations and individuals, to work towards improved general weather literacy.

Recommended courses of action by the group included the promotion of educational activities, the dissemination of up-to-date information, the education of the general populace, and the provision of a clearing-house service.

The conference perceived that the benefits of their proposed action plan would be a greater interest in the practical applications of science and mathematics in schools and a broader scientific appreciation by the general public.

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