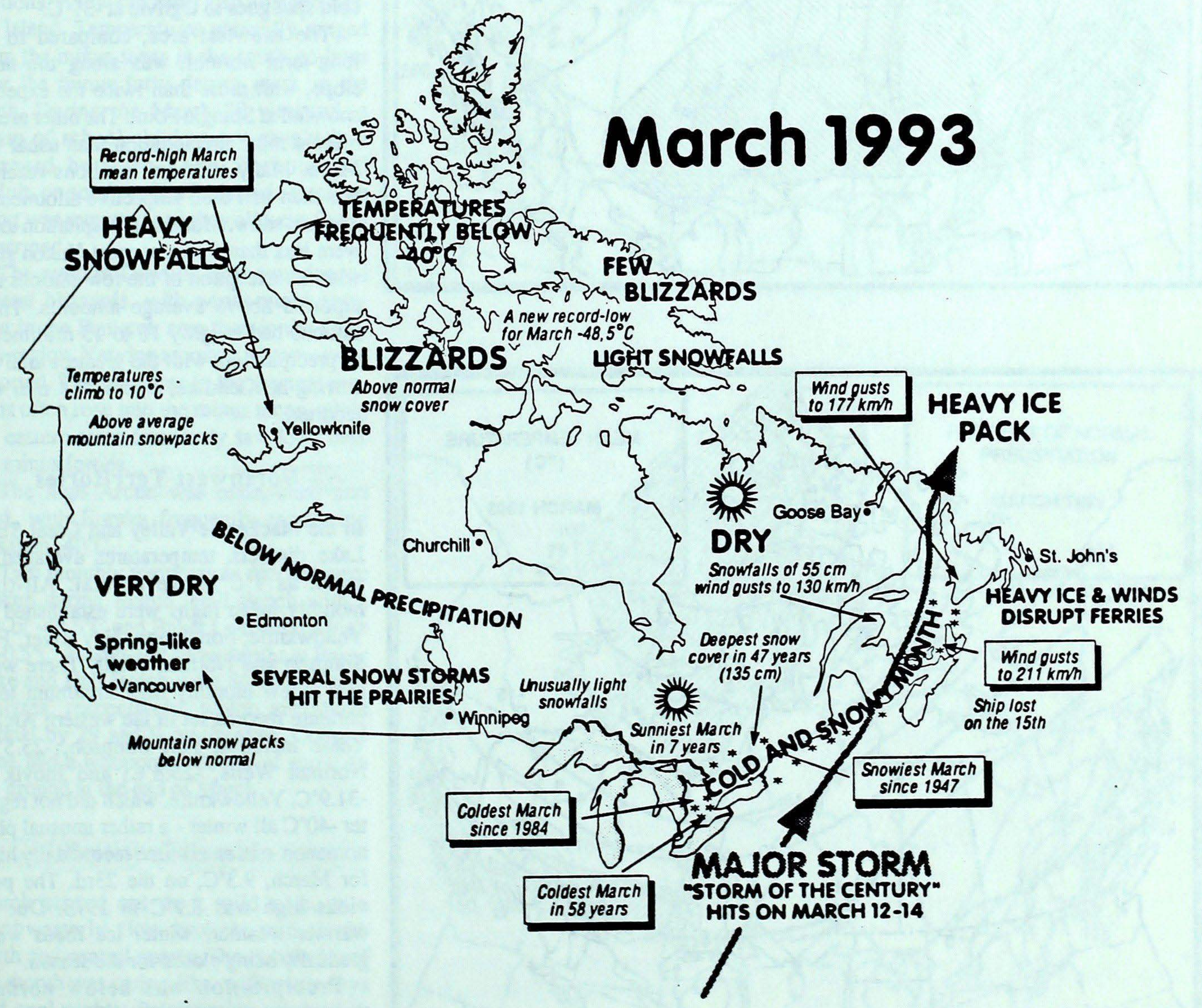
Environment Canada Environnement Canada

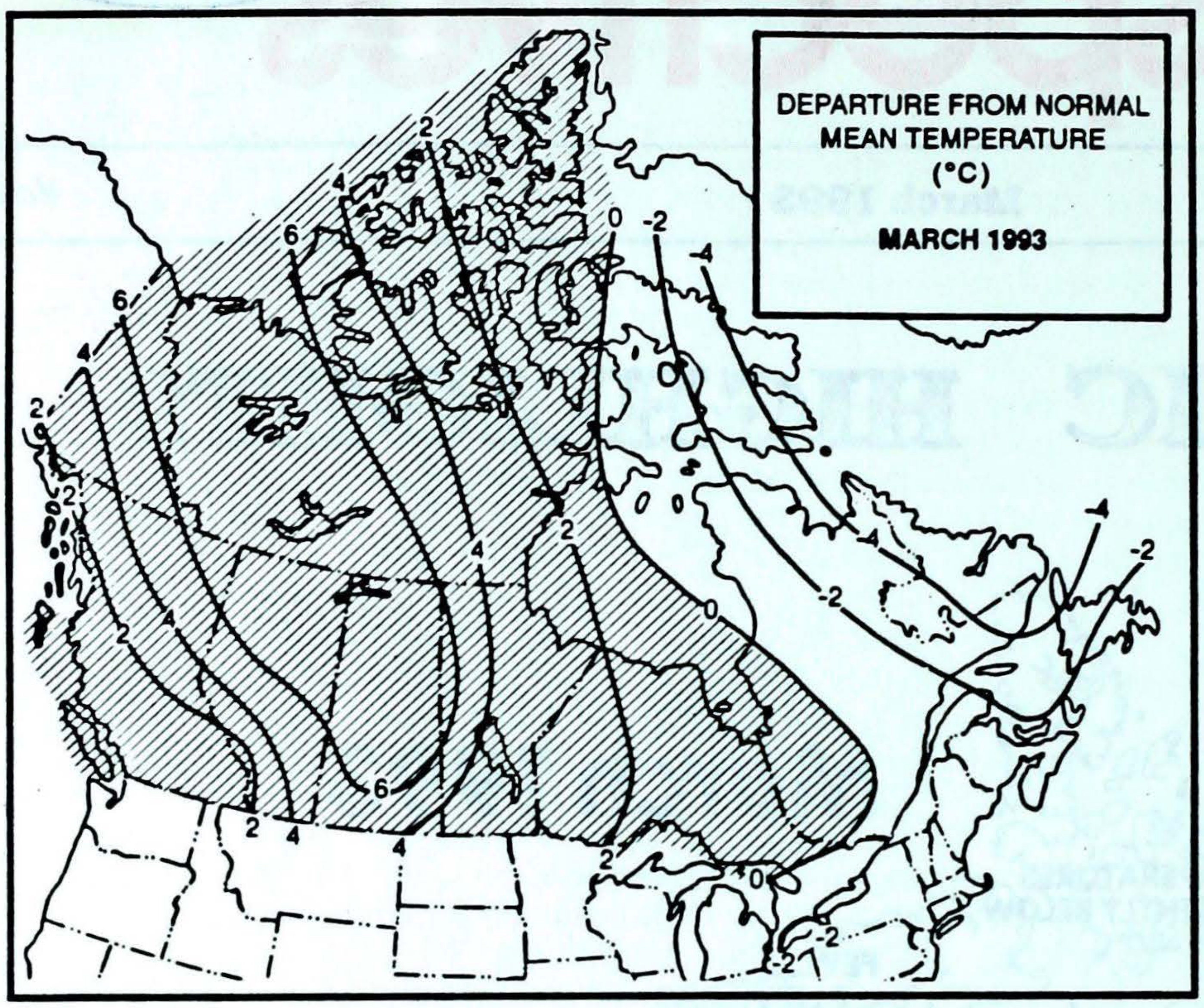
Climatic Perspectives

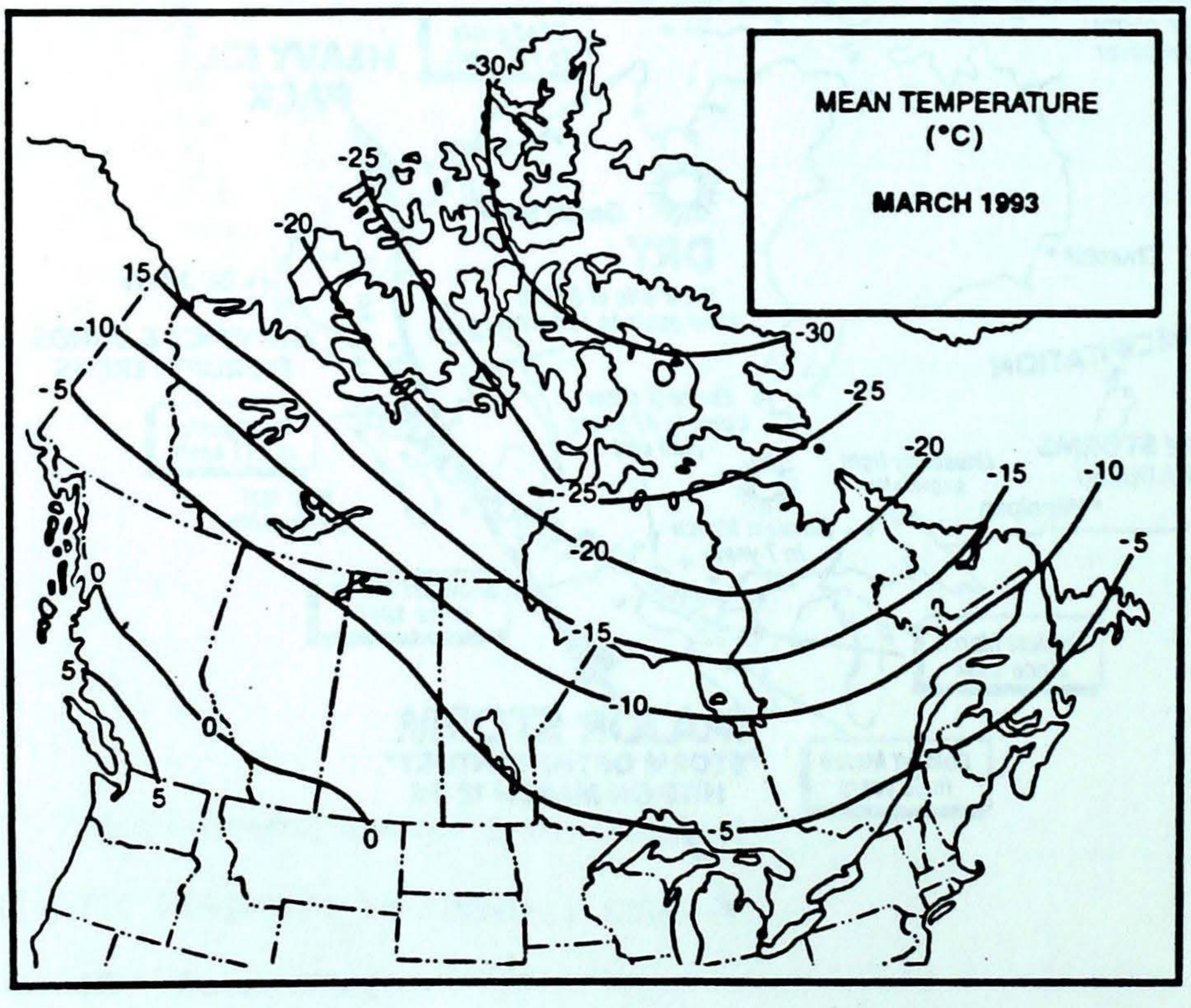
Monthly + Winter 1992/93 Review March 1993 Vol. 15

CLIMATIC HIGHLIGHTS



Canada





Across the country

Yukon

Mean monthly temperatures across the Territory ranged from 2°C below to nearly 6°C above average for the month of March. The warmest temperature readings were registered at Carmacks, Drury Creek, Haines Junction, Johnson's Crossing, Ross River and Tuchitua; they all reached 10°C, at one time or another this month. However, many stations still managed to register minimums in the minus thirties. The cold spot goes to Ogilvie at -39°C.

The snowiest area, compared to the long-term normal, was along the north slope, with more than twice the expected snowfall at Shingle Point. The other area to receive more precipitation than usual was Mayo. Many southern locations received less than half their respective allotment of rain and snow. Monthly precipitation totals were less than 5 mm at most Yukon sites, with the exception of the few stations that reported above average amounts. These stations had roughly 10 to 15 millimetres of precipitation, with the greatest total occurring at Klondike, where 27.4 mm was reported.

Northwest Territories

In the Mackenzie Valley and Great Slave Lake districts, temperatures averaged as much as 7°C above normal. All-time monthly mean highs were established at: Yellowknife, Fort Smith, Hay River, Fort Simpson and Norman Wells. There were also a few monthly high minimum temperature records set in the western Arctic. These included: Fort Simpson, -25.5°C; Norman Wells, -25.8°C; and Inuvik at -31.9°C. Yellowknife, which did not register -40°C all winter - a rather unusual phenomenon - set an all-time record daily high for March, 9.3°C, on the 23rd. The previous high was 8.9°C in 1973. Due to warmer weather, winter ice roads were gradually being closed for the season.

Precipitation was below normal throughout the Mackenzie Valley, with Hay River receiving only 4 mm, compared to a normal of 18 mm. Yellowknife received slightly more moisture than normal.

Fort Smith reported 25 hours more sunshine than normal and Fort Simpson was up 22 hours. Elsewhere, across the Territory, hours of bright sunshine were slightly below normal.

In the Keewatin, a northwesterly circulation dominated, keeping temperatures colder, as compared to the west. Although this pattern was interrupted by a couple of milder days during the month, blizzards were common.

The Baffin region was generally clear, but several weather systems gave light snowfalls to the southern and northwestern sections. A few blizzards also affected Baffin Island. Temperatures generally ranged from the minus teens in the south, to lows near the minus forty degree mark in the north. During the March 20 weekend, a group of school children got caught in a blizzard between Lake Harbour and Iqaluit, on southern Baffin Island. A rescue effort was mounted and they all were found unharmed.

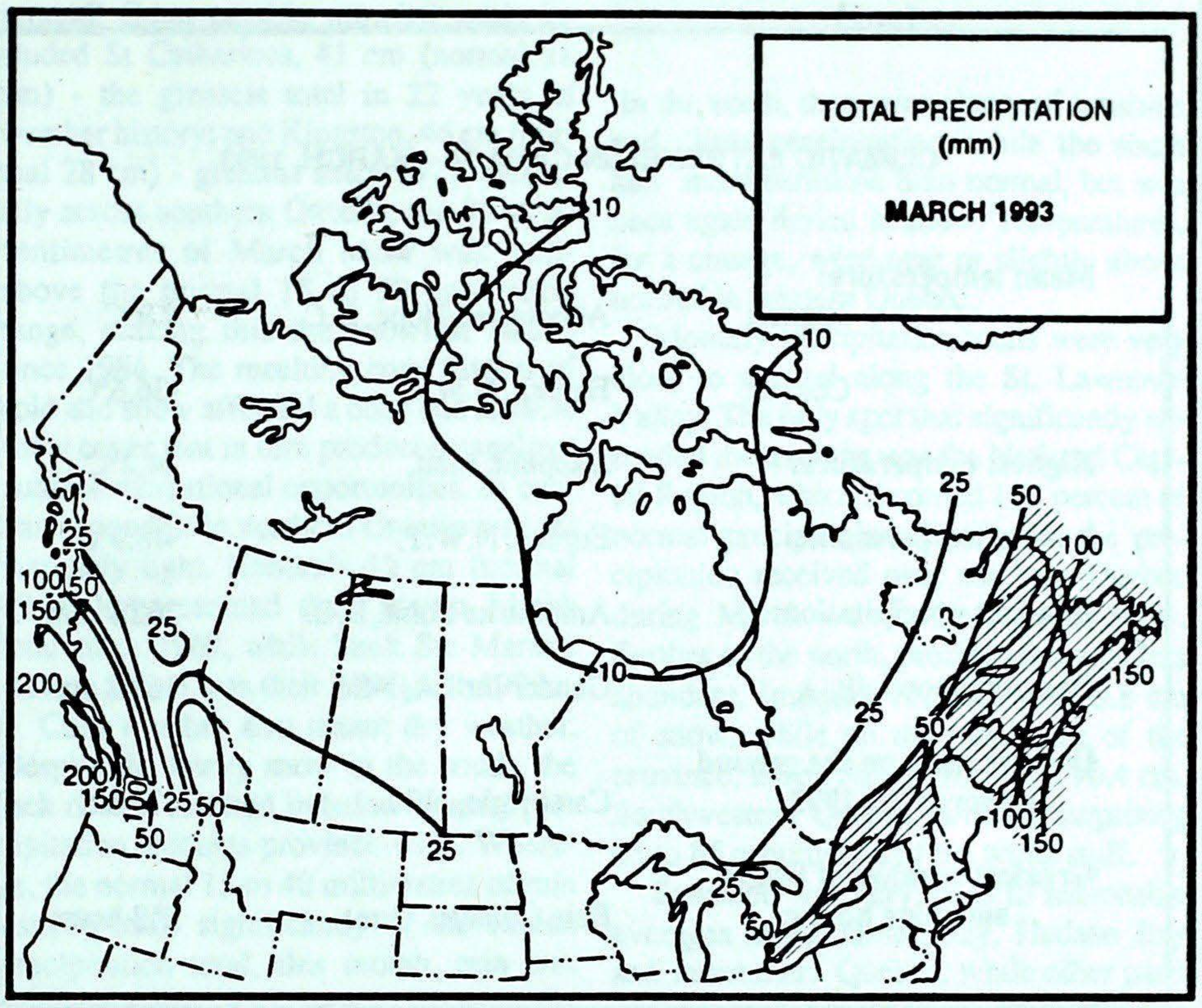
The western Dewline sites experienced several blizzards, with winds more common in the Paulatuk area than in the Pelly Bay region. Varying amounts of snow were reported. Temperatures in the western sections often rose into the minus teens, while the eastern areas frequently saw lows near the minus forties.

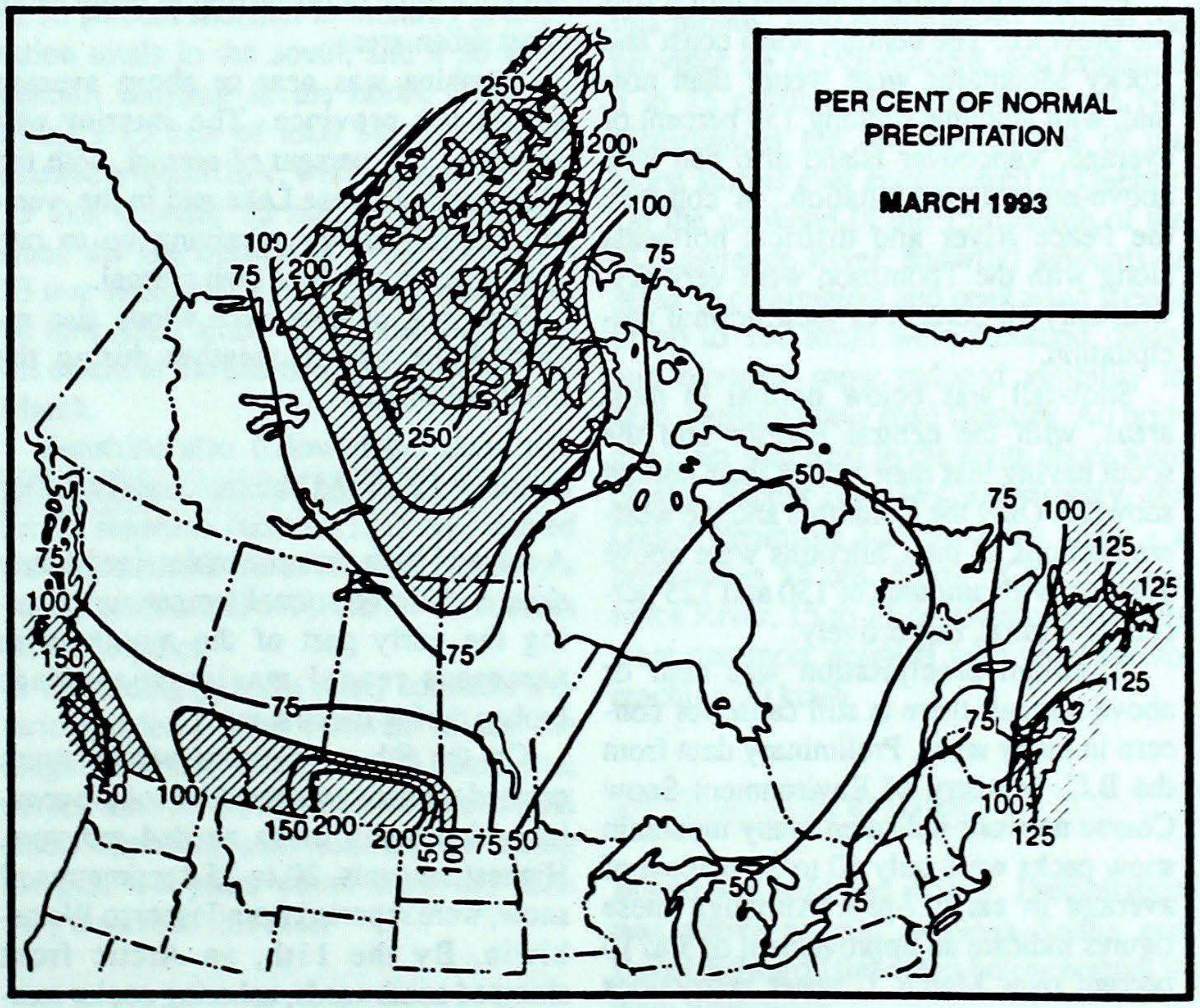
The high Arctic was often clear and cold, with Eureka frequently registering less than -40°C.

Two monthly temperature records were broken during March, Hall Beach with a low of -48.5°C and Baker Lake with a high of -0.5°C. Month-end snow depths at Baker Lake and Hall Beach were 84 and 50 centimetres, respectively, which are above normal by 29 and 9 centimetres. Coppermine had a whopping 100 cm of snow on the ground at the end of March.

British Columbia

March started out on a mild note, as a southwesterly flow brought rain to the north and central coasts. The remainder of the month was spring-like, with warm days and cool nights. Precipitation returned to the coast after mid-month, but amounts were near normal and it remained mild, especially in the extreme northeast.





CLIMATIC EXTREMES IN CANADA - MARCH, 1993

Mean temperature:			
	Highest	Abbotsford/Hope, B.C.	7.9°C
	Coldest	Eureka, N.W.T.	-36.6°C
Highest temperature:		Dauphin, Man.	24.2°C
Lowest temperature:		Eureka, N.W.T.	-48.9°C
Heaviest precipitation:		Amphitrite Point, B.C.	362.9 mm
Heaviest snowfall:		Gander Int'l A, Nfld.	163.8 cm
Deepest snow on the ground on March 31, 1993		Cartwright, Nfld.	177 cm
Greatest number of bright sunshine hours:		Baie Comeau, Que.	213 hours

Precipitation varied considerably across the province. The central, north coast and Rocky Mountains were wetter than normal, with amounts running 150 percent of average. Vancouver Island also had well above-normal precipitation. In contrast, the Peace River and districts northeast along with the Thompson were very dry, with only 10 percent of their normal precipitation.

Snowfall was below normal in most areas, with the central interior and the south having less than half of their normal snowfall. Only the Columbia and the western sections of the Chilcotins were above average, with amounts of 150 and 125 percent of normal, respectively.

Although precipitation was near or above normal, there is still cause for concern in many areas. Preliminary data from the B.C. Ministry of Environment Snow Course network indicated many mountain snow packs were only 60 to 80 percent of average in early April. Although these figures indicate an improvement of 5 to 10 percent over March 1, water restrictions remain a topic of discussion in many south coast urban areas.

Sunshine was near or above average across the province. The interior was generally 110 percent of normal, with the areas around Dease Lake and in the western central interior receiving up to one quarter more sunshine than normal.

The lack of gale-force winds also reflected the benign weather during the month of March.

Alberta

A ridge of high pressure maintained sunny skies and above-normal temperatures during the early part of the month, with numerous record maximum readings broken during the first week.

On the 8th, a vigorous winter storm crossed the southern two thirds of the province, depositing much needed moisture. Highest amounts, 20 to 25 centimetres of snow, were reported from Jasper to Wetaskiwin. By the 11th, an Arctic front slumped southwards, ushering cooler temperatures and more light snow. The front continued to slide southwards, with a cold, dry air mass spreading across most of the province.

Another Pacific disturbance pushed into the southern half of Alberta by the middle of the month, bringing with it much needed moisture. Snowfall amounts along the mountains ranged from 65 cm in Waterton Park to 20 cm at Jasper. Across the grass lands snowfalls ranged from 5 to 10 centimetres. An Arctic ridge brought winter temperatures to the whole region, with new record minimums set at Rocky Mountain House (-29.0°C) and Jasper (-26.1°C), on the 16th.

As spring arrived on the 21st, so did the record warm weather. Numerous records were broken, with Medicine Hat being the first to climb into the twenties, but rain and flurries were reported in the mountains, with the Jasper town site receiving 10 mm of rain, while Marmot Basin reported 22 cm of snow on the 23rd.

On March 26, the attention shifted southwards to a developing snow storm in the northwestern States. The initial surge of moisture gave Calgary a record snowfall for March 26, of 10.2 cm, with the snow spreading as far north as Red Deer. The snow continued until the 28th, with Coronation having a four-day record snowfall of 40 cm. In contrast, northern regions remained sunny and warm, with High Level setting a new record maximum on the 28th. Cloud, scattered showers and flurries dominated the weather across much of the region at the end of the month, while the mountain parks enjoyed double digit temperatures and sunshine.

Manitoba and Saskatchewan

The month was mild throughout the region, but precipitation was highly variable. Many areas saw daytime temperatures peak in the high teens or low twenties at least once during the month. However, the area with the greatest snow cover, southeastern Manitoba, did not reach double digits at all.

At Dauphin, Man., mild weather rapidly melted the scant snow cover, and prompted a local golf course operator to open the golf course for the season - perhaps the earliest opening ever. However, only days after the course was opened, 15 to 20 centimetres of snow buried the town of Dauphin. This same storm also affected southern Saskatchewan, with 15 to 25 centimetres of fresh snow. The 25.0 cm that fell at Broadview, Sask. was the highest single day March snowfall since that station opened in 1938. Total precipitation amounts varied, from almost three times the normal in parts of southern Saskatchewan, to no snow, in west-central Saskatchewan. The areas with above-normal precipitation were the southern third of Saskatchewan, the southwest corner of Manitoba and a small area northwest of Thompson, in northern Manitoba. More than twice the normal fell near the Alberta border of southern Saskatchewan and south of the Trans-Canada Highway to east of Moose Jaw. Less than half of the normal precipitation fell across central Saskatchewan, west-central, southeastern and northeastern Manitoba.

Sunshine amounts were generally within 10 hours of normal, although a few sites were sunnier than average by up to 25 hours. Kindersley tallied the least sunshine, with 150.3 hours, while Cree Lake tallied the most, 209.6 hours.

Ontario

March came in cold and wintry and remained lion-like, especially in the south, until the final few days of the month. In addition, like the February before, the bulk of the snow and stormy weather was confined to the southern portions of the province, with eastern Ontario, in particular, receiving near-record snowfalls.

Monthly mean temperatures were 1 to 2 degrees colder than normal south of Lake Nipissing, giving most of southern Ontario their coldest March since 1984. However, in northern Ontario, relatively mild mean temperatures prevailed, resulting in the mildest March for at least 3 years.

Snowfall portrayed a similar pattern to the temperature regime, with above-normal snow in the south and very little in the north. Ottawa bore the brunt of the March snowstorms, with an enormous 93 cm total. At one point in mid-March, Ottawa reported their deepest snow cover in 47 years, as 135 cm of snow covered the ground! Other notable snowfall totals included St Catharines, 41 cm (normal 18 cm) - the greatest total in 22 years of weather history; and Kingston, 46 cm (normal 28 cm) - greatest since 1977. Generally across southern Ontario, the 30 to 50 centimetres of March snow was well-above the normal 15 to 30 centimetre range, making this the snowiest March since 1984. The resulting combination of cold and snow afforded a deep and reliable snow cover that in turn produced excellent outdoor recreational opportunities. In contrast, snowfall in northern Ontario was remarkably light. Kenora's 12 cm (normal 29 cm) represented their lowest March total since 1969, while Sault Ste Marie's meagre 11 cm was their least since 1973.

Cold weather also meant dry weather. Despite the heavy snow in the south, the lack of rain resulted in below-normal precipitation amounts province-wide. Whereas, the normal 15 to 40 millimetres of rain usually adds significantly to the March precipitation total, this month, rain was minimal at best. At Toronto's Pearson Airport for example, only 7 mm fell - the least March rain since 1971. The result was a 10 to 30 percent shortfall in monthly precipitation totals in the south, and a 50 to 70 percent shortfall in the north. Sault Ste Marie's 15 mm of total March moisture marked a record low, while Kapuskasing's 15 mm (normal 55 mm) was their least since the site opened in 1938. Sudbury's 23 mm (least since 1960), and Muskoka's 40 mm (least since 1962), also illustrated the extent of the dearth of precipitation this March.

Sunshine also followed the same pattern. While London's lowly 85 hours of bright sunshine (normal 121) represented the cloudiest March in 58 years; the Soo's 168 hours (normal 149) was the sunniest in the last 7 years.

Accordingly, while many southern Ontario residents were relieved to see the toughest winter in the last 10 years end; others, such as snowplough owners and ski resort operators will celebrate, as during the past few years winter snow has been very elusive in this area.

Quebec

In the north, there was plenty of sunshine and little precipitation, while the south had more sunshine than normal, but was once again buried in snow. Temperatures, for a change, were near or slightly above normal in western Quebec.

Monthly precipitation totals were very close to normal along the St. Lawrence Valley. The only spot that significantly exceeded the average was the National Capital Region, which recorded 133 percent of normal precipitation. Nearly all the precipitation received over southern Quebec during March was in the form of snow. Further to the north, precipitation was less abundant. Inukjuak received only 3.8 cm of snow, while on the other side of the province, Blanc Sablon recorded 90.4 cm. Southwestern Quebec tallied a surprising 65 to 85 centimetres of the white stuff.

Sunshine was very close to seasonable averages along James Bay, Hudson Bay and in southern Quebec, while other parts of the province received 15 to 25 percent more sunshine than usual.

There were a number of weather events this month. Two disturbances crossed the province on March 6 and 8, and produced 5 to 15 centimetres of snow. These two disturbances led the way to one of the worst storms ever encountered in Quebec. On the weekend of the 13th, south of the St. Lawrence River, snowfall amounts of 30 to 45 centimetres and peak wind speeds of up to 130 km/h were recorded. Snow and blowing snow reduced visibility to zero, causing many road closures. All bridges from Montreal to the south shore were closed, except one. Not surprisingly, the Gaspé Peninsula had the most snow - a horrendous 55 cm. North of the St.Lawrence River, 15 to 25 centimetre snowfalls were common, coupled with wind speeds reaching 70 km/h.

Maritimes

March was cold and stormy. Precipitation was above normal in Nova Scotia and Prince Edward Island, but below normal in New Brunswick.

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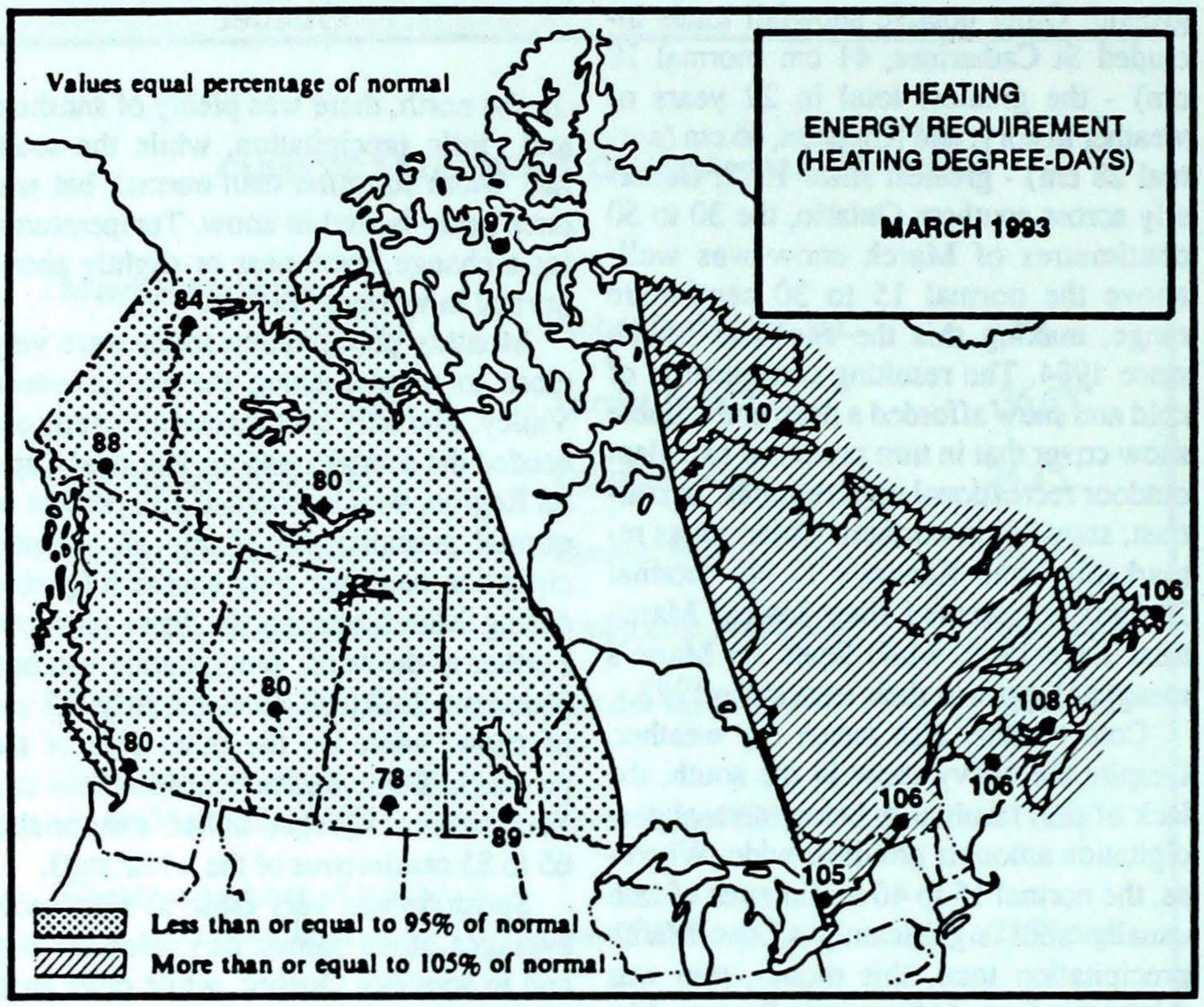
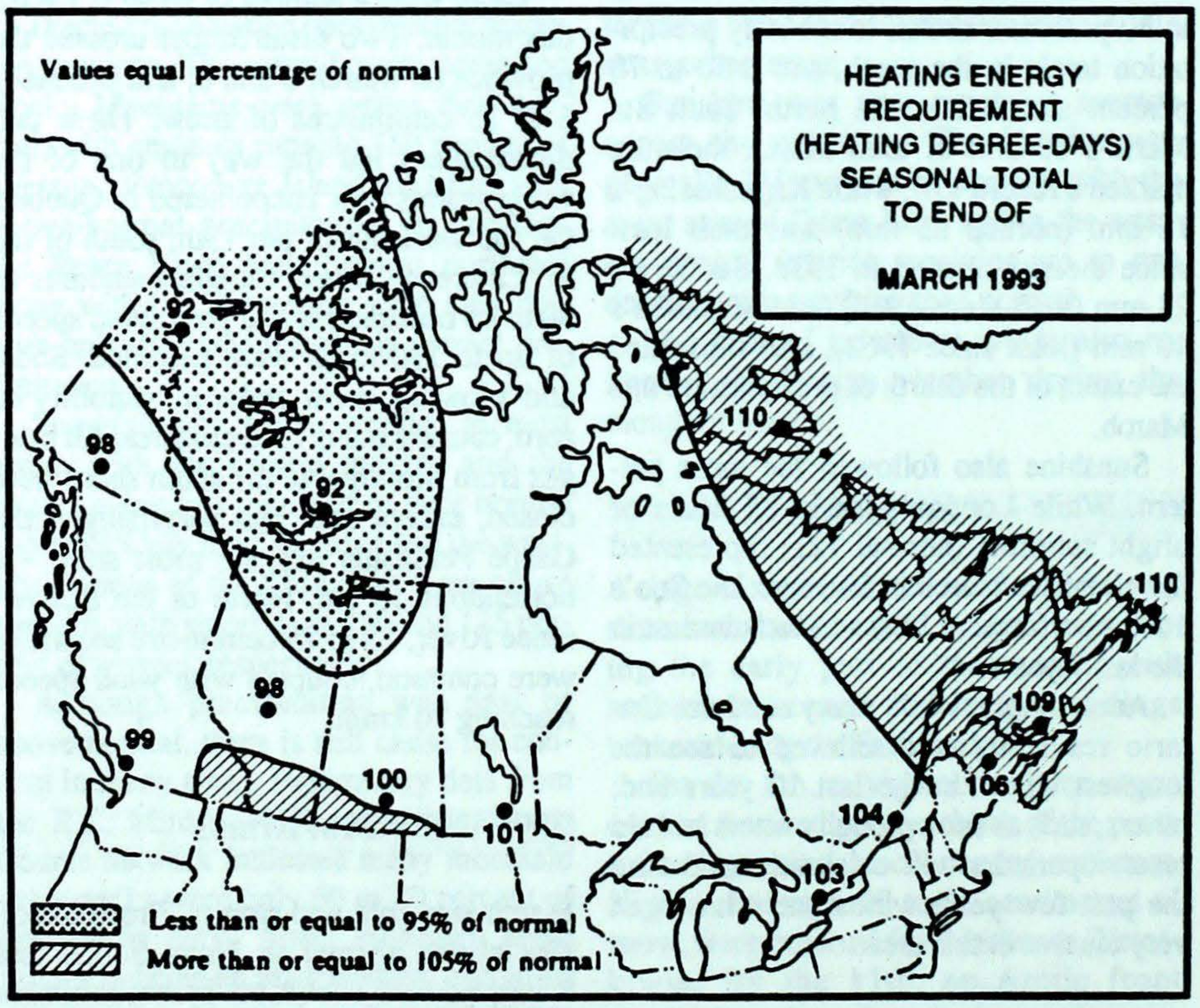


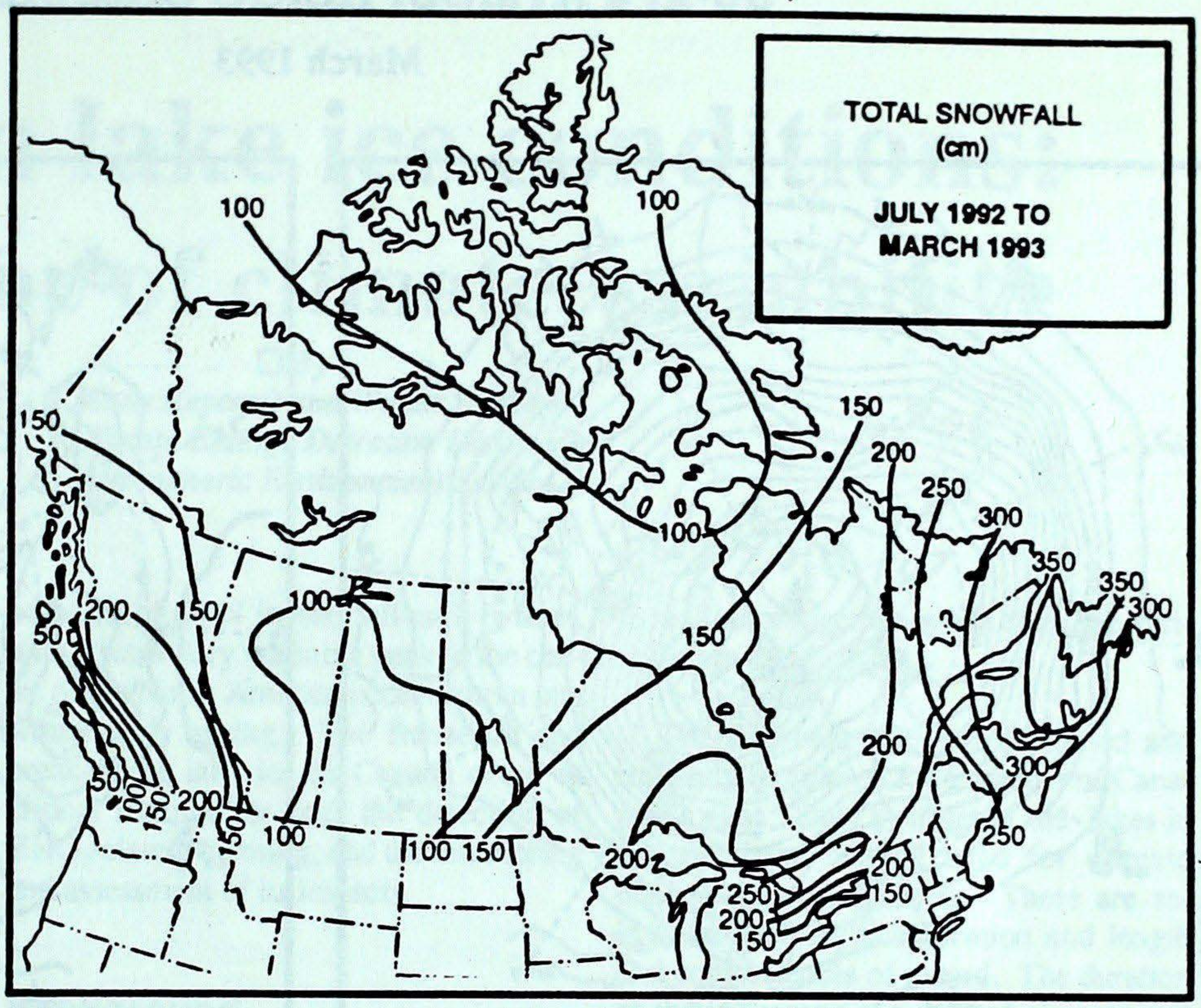


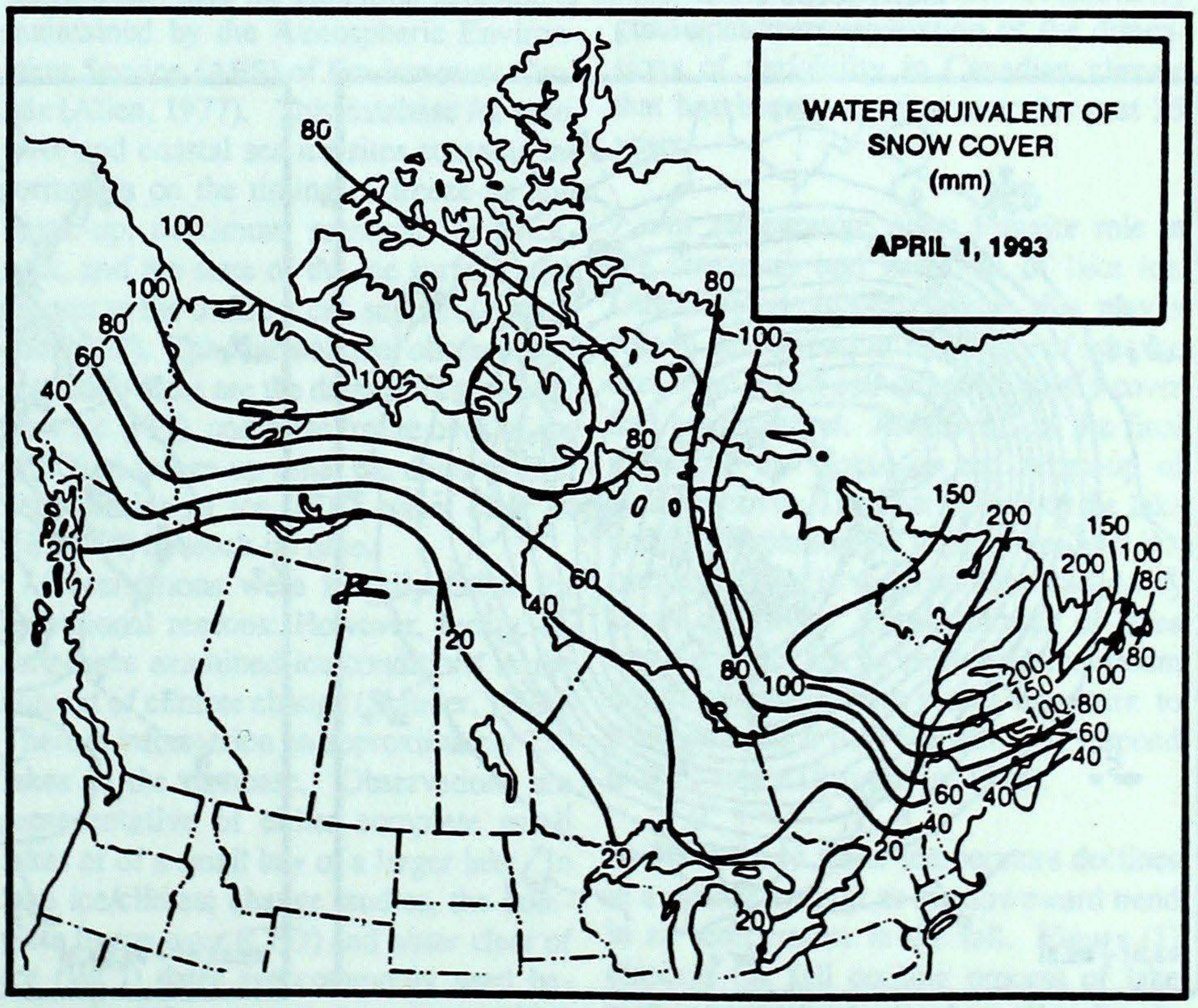
SEASONAL TOTAL OF HEATING DEGREE-DAYS TO END OF MARCH

	1993	1992	NORMAL
BRITISH COLUMBIA			
Kamloops	3586	2693	3271
Penticton	3196	2593	2984
Port Hardy	2797	2514	2879
Vancouver	2477	2142	2454
Victoria	2512	2207	2500
YUKON TERRITORY			
Whitehorse	5775	5313	5909
NORTHWEST TERRITORIES			
Iqaluit	8612	8070	7854
Inuvik	7682	8234	8306
Yellowknife	6606	7212	7184
ALBERTA			
Calgary	4540	3712	4478
Edmonton Mun.	4599	4112	4704
Grande Prairie	5247	4652	5268
SASKATCHEWAN			
Estevan	4970	4291	4727
Regina	5033	4517	5054
Saskatoon	5245	4746	5242
MANITOBA			
Brandon	5394	5169	5276
Churchill	7325	7507	7360
Dauphin	5070	4991	5266
Winnipeg	5190	4841	5116
ONTARIO			
Kapuskasing	5472	5562	5406
London	3585	3421	3484
Ottawa	4157	4203	4037
Sudbury	4697	4699	4590
Thunder Bay	4877	4853	4829
Toronto	3576	3393	3487
Windsor	3113	3007	3114
QUEBEC			
Baie Comeau	5237	5156	4935
Montréal	4093	4108	3907
Québec	4556	4645	4361
Sept-Îles	5506	5362	5035
Sherbrooke	4497	4485	4409
Val d'Or	5444	5437	5176
NEW BRUNSWICK			
Fredericton	4192	4151	3951
Moncton	4203	4132	3884
NOVA SCOTIA			
Sydney	3837	3758	3514
Yarmouth	3540	3336	3236
PRINCE EDWARD ISLAND			
Charlottetown	4073	3945	3746
NEWFOUNDLAND			
Gander	4520	4367	3962
St. John's	4045	3987	3683

SEASONAL SNOWFALL TOTALS (cm) TO END OF MARCH

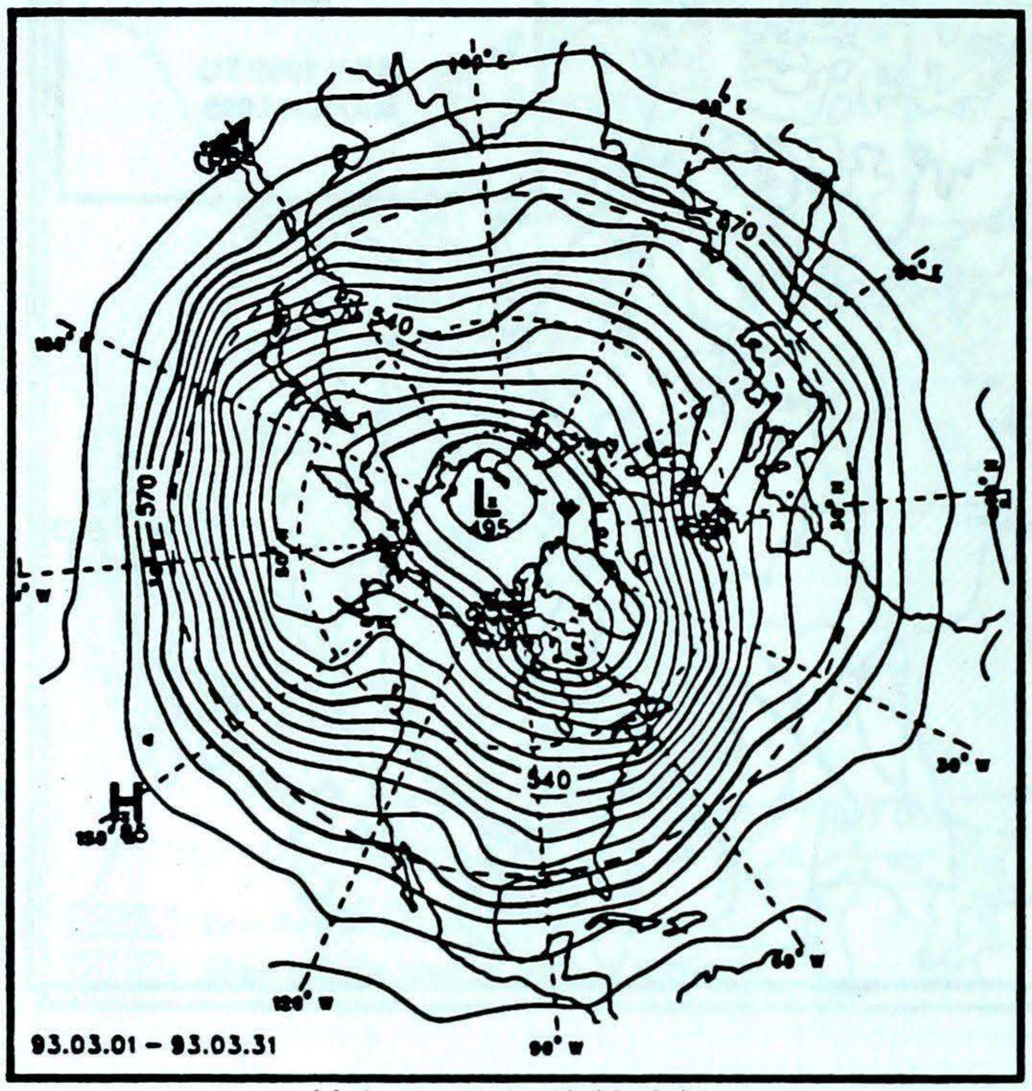
	1993	1992	NORMAL
BRITISH COLUMBIA			
Kamloops	91	32	91
Port Hardy	37	1	71
Prince George	233	204	230
Vancouver	68	2	60
Victoria	46	5	50
YUKON TERRITORY			
Whitehorse	183	200	122
NORTHWEST TERRITORIES			
Iqaluit	147	134	129
Inuvik	186	135	145
Yellowknife	122	175	122
ALBERTA			
Calgary	136	63	116
Edmonton Mun.	103	128	117
Grande Prairie	96	166	164
SASKATCHEWAN			
Estevan	100	69	98
Regina	104	79	102
Saskatoon	67	98	102
MANITOBA			
Brandon	77	136	104
Churchill	128	209	150
The Pas	87	234	145
Winnipeg	112	97	112
ONTARIO			
Kapuskasing	251	249	285
London	214	216	199
Ottawa	303	242	218
Sudbury	190	261	229
Thunder Bay	170	272	193
Toronto	136	77	124
Windsor	131	31	113
QUEBEC			
Baie Comeau	168	277	337
Montréal	201	201	224
Québec	217	228	326
Sept-Îles	304	271	388
Sherbrooke	280	271	289
Val d'or	196	283	285
NEW BRUNSWICK			
Fredericton	206	188	268
Moncton	320	421	311
NOVA SCOTIA			
Sydney	156	363	287
Yarmouth	243	216	201
PRINCE EDWARD ISLAND			
Charlottetown	364	327	301
NEWFOUNDLAND			
Gander	420	353	342
St. John's	258	325	312



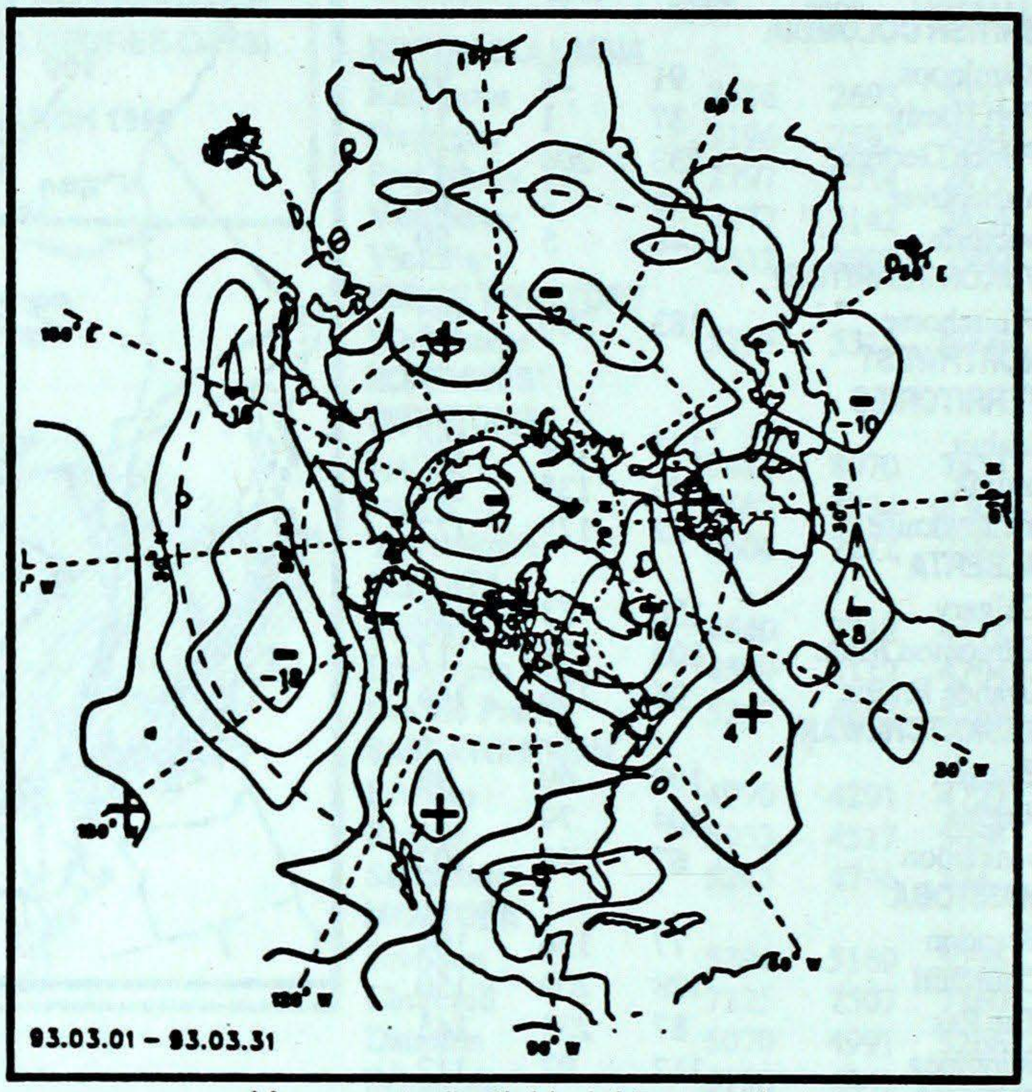


50-kPa ATMOSPHERIC CIRCULATION

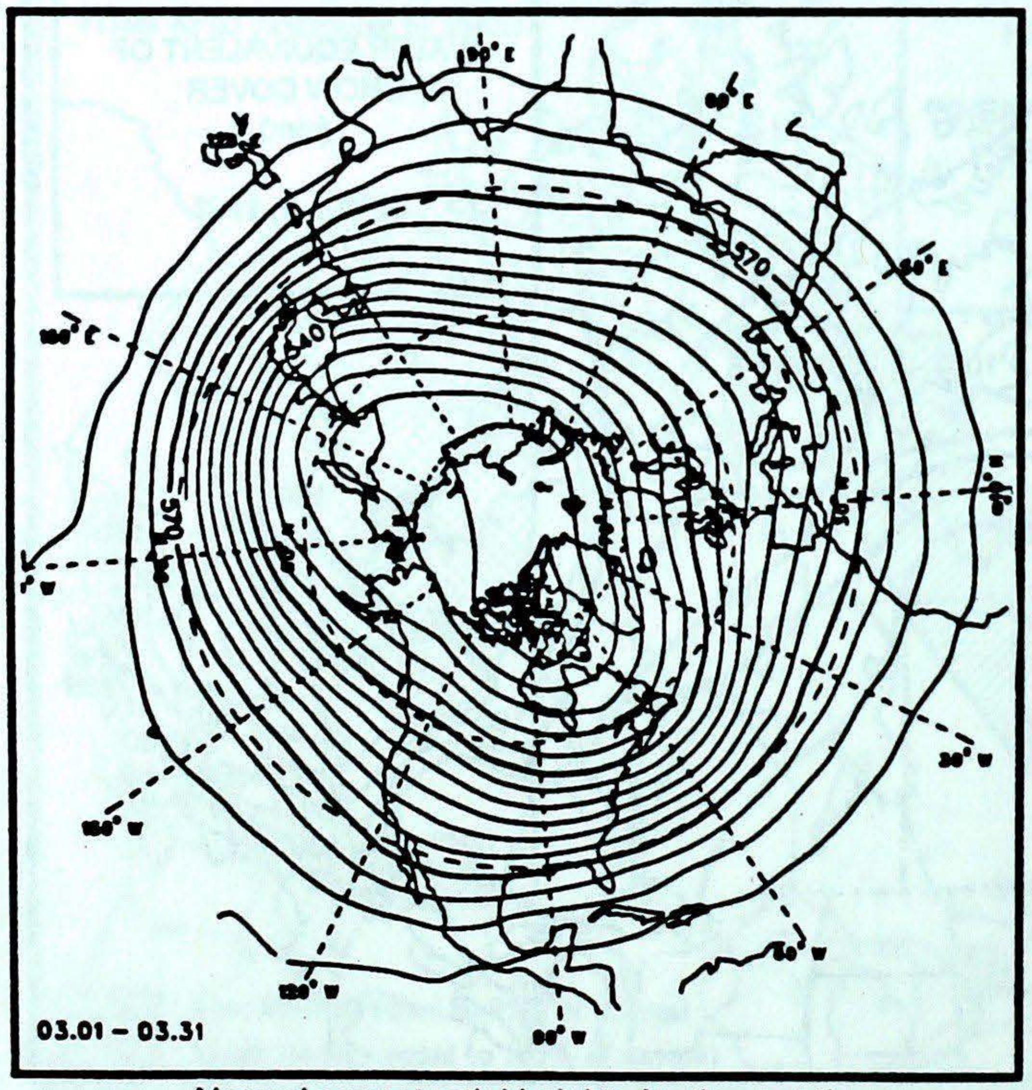
March 1993



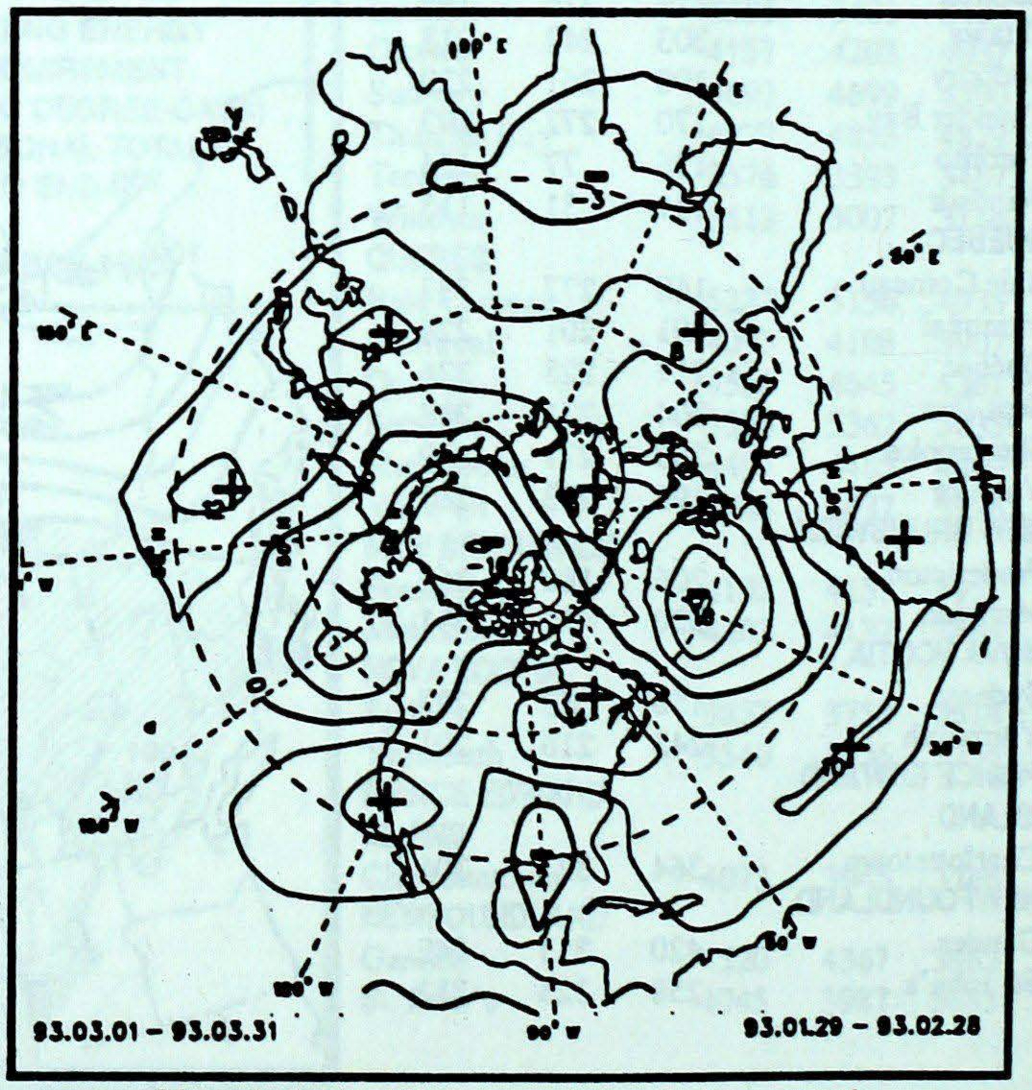
Mean geopotential heights
- 5 decametre interval -



Mean geopotential height anomaly
- 5 decametre interval -



Normal geopotential heights for the month
- 5 decametre interval -



Mean heights difference w/r to previous month
- 5 decametre interval -

Canadian lake ice conditions: an indicator of climate variability

□ *by*
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The analysis of the temporal patterns of freeze-up and break-up of lake ice in Canada has both practical and theoretical value. The ability to accurately predict freeze-up and break-up dates would be of great benefit to marine and overland transportation operations, which must take maximum advantage of lakes in their ice-free or ice covered states. The analysis of seasonal lake ice condition data could also provide early detection of a rise in global temperatures due to increased concentrations of carbon dioxide (CO_2) and other radiatively *active greenhouse gases (GHG's) in the atmosphere. In addition, it would provide baseline climate/cryosphere relationships upon which climate change impact related hypotheses might be developed.*

Freeze-up and break-up records from middle and high latitudes of North America could provide a good index of changing temperatures in the transition seasons. Trends toward later freeze-up and earlier break-up patterns could indicate warming due to increased atmospheric CO_2 concentrations (Tramoni et al., 1985). General circulation model (GCM) CO_2-doubling experiments predict that higher latitudes will experience the greatest temperature increases (Manabe and Stouffer, 1980). This is mainly due to albedo feedback mechanisms and northern air mass stability. Also, these experiments indicate that the greatest warming would be north of 60°N in late fall-early winter, with a secondary warming peak in the centre of the North American continent in late winter-early spring. The freeze-up and break-up of lake ice in Canada occur at critical seasons for both the detection of GHG-related warming, and the monitoring and assessment of its impacts.

Background

A Canadian lake ice condition database is maintained by the Atmospheric Environment Service (AES) of Environment Canada (Allen, 1977). This database for lake, river and coastal sea ice sites contains information on the timing of freeze-up and break-up, maximum seasonal ice thickness, and the state of the ice surface with respect to the traffic it can support (Anderson, 1987). The four standard observed ice condition dates are the dates of first permanent ice (FPI), complete freeze over of ice (CFO) at freeze-up time, the dates of first deterioration of ice (FDI), water clear of ice (WCI) at break-up time.

Observations were initially taken for operational reasons: However, recent efforts have examined ice conditions in the context of climate change (Skinner, 1992). There is information on approximately 250 lakes in the database. Observations are representative of either complete small lakes or of a small bay of a larger lake. In lake ice/climate change studies, the complete freeze over (CFO) and water clear of ice (WCI) dates are commonly used because these dates contain less observer bias than the other dates. This reduces the potential inhomogenieties and thus, the variability in the datasets.

The ice event dates are identified and routinely monitored for a number of Canadian Lakes. Only a subset of the lakes in the database can be used for climate change detection studies. These are selected based on their location and length and completeness of record. The duration of the ice season is a derived element and is also maintained in the database. The lakes in the database provide a reasonably good spatial representation of the dimensions of variability in Canadian climate that has been occurring over the past 35 years.

Air temperature plays a major role in the freeze-up and break-up of lake ice. Other meteorological factors that play a role in the formation and decay of lake ice are: wind speed and direction, cloud cover and precipitation. All can affect the final stages of the freeze-up and break-up of lake ice cover. The heat budget of the lake and its morphological features are also important factors in the formation and decay of an ice cover. Characteristics of lakes such as their fetch, mean and maximum depth, basin geometry and exposure to wind determine how the lake will respond to the climate (Ragotzkie, 1978).

The surface water temperature declines in a similar manner as the downward trend in air temperature in the fall. Figure (1) displays the fall cooling process of lake surface water temperatures and decline in the overlying air temperature. There is a strong relationship between air temperature and freeze-up dates because of sensible heat exchange dominating the cooling process. During the freeze-up process, ice forms around the shoreline of the lake when the mean daily water temperature there drops to 0°C. The ice builds outwards as the surface water temperature cools. The deepest parts of the lake are the last to freeze. Light to moderate winds speed up the freezing process by removing heat from the water and causing the water to cool, due to increased evaporation. On the other hand, strong winds retard ice formation by breaking up the weak ice that has managed to develop.

The break-up process of ice on a lake is dependent on the temperature regime, the snow cover present on the ice surface and wind conditions. Snow cover retards the break-up of ice as it must first melt before the ice itself can melt. Once the snow has melted, the reflective properties of the lake surface changes, allowing an increased amount of solar radiation to be absorbed at the surface. If thawing temperatures are high enough, the ice weakens and begins to melt. The wind acts to free the ice from the shoreline and to mechanically break it up.

Interrannual variability

Mean freeze-up and break-up dates can be converted into Julian dates, or simply, days numbered from 1 to 365, from January 1 to December 31, and thus, provide a quantitative index for use with coinciding meteorological records. Statistical studies have described the relationship between ice events and meteorological conditions (Skinner, 1992). By employing regression analysis, scientists have shown that mean air temperature and lake ice events are strongly related to one another. The results obtained from these analyses have been used to make inferences on how future temperature anomalies would effect the lake ice regime.

Simple regression models relate specific air temperature parameters for example, daily, monthly or bi-monthly average air temperatures, with the coinciding freeze-up and break-up dates, or ice season duration. The slope of the regression equation yields an estimate of how a future change in air temperature might affect the lake ice regime.

Time series analysis has proven useful in determining how the lake ice events have changed over the recorded history of the lake. Some studies have affixed a weighted mean to the time series to reduce short term fluctuations that may obscure any trend in the time series. Freeze-up dates occurring later and break-up dates occurring earlier would signal warmer temperatures during that specific season. The duration of the lake ice season is calculated as the number of days between the complete freeze-over (CFO) and the water clear of ice (WCI) dates. A reduction in the length of the ice season would indicate a warming taking place in either/or both of the transition seasons.

Figures (2) and (3) show the mean dates for freeze-up and break-up in Canada. These dates were calculated by averaging the dates of freeze-up or break-up. They are based on a minimum of five years of observation up to 1973. The pattern for freeze-up shows the lakes generally freezing earlier in the north and then progressing southward. The national break-up pattern is the opposite. In general, lakes in the south begin to break-up first and the progression is northward. Both maps show local differences due to elevation and the size of larger lakes. A change towards a warmer climate would likely produce a general northward shift in both freeze-up and break-up dates.

A number of lakes with high quality records have been selected to show the changes that have occurred in their ice conditions over the years. **Figure (4)** shows the time series for complete freeze over for seven selected lakes in Canada. As can be seen from these time series, only slight changes are occurring in the freeze-up dates. Slight trends towards earlier freeze-up are actually occurring with some lakes. Lac St. Jean, Quebec was the only lake in this group that showed a trend towards later freeze-up dates. Water clear of ice dates have shown more pronounced changes, as can be seen in Figure (5). Break-up dates are occurring about one week earlier at the majority of the selected lakes. The exception is Knob Lake, where a slight trend towards later break-up is indicative of the general cooling in this re-

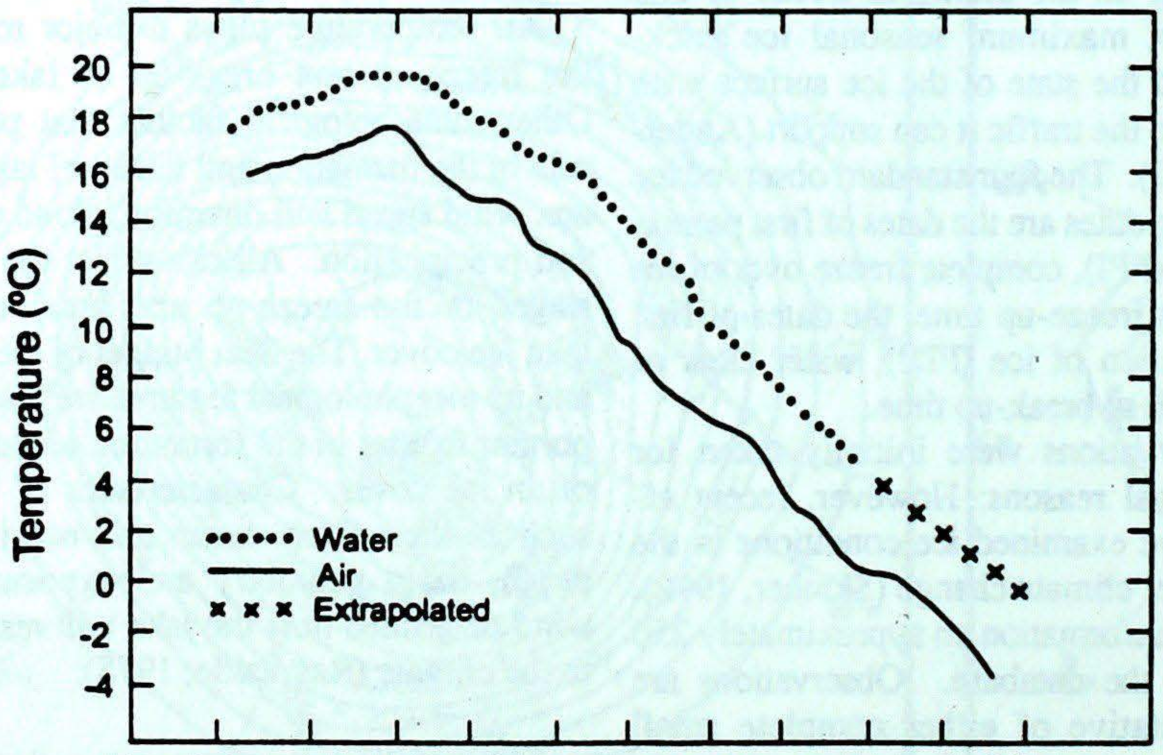

Figure 1 Average trends of surface water temperature (1961-80) and air temperature (1959-82) for July through December at Lake Saima, Finland (Palecki, M.A. and G.G. Barry, 1986)

gion over the past 15 years. The observed winter and spring warming appears to have affected the amount of ice forming on the lakes and also the onset of break-up in the spring. **Figure (6)** shows the ice season duration time series for the selected lakes in Canada. The trends towards earlier break-up appear to be overriding the changes occurring with the freeze-up dates. The trends for most lakes, with the exception of Knob Lake in Quebec and Back Bay on Great Slave Lake in the Northwest Territories, show up to a one week change in the length of the ice season.

The changes occurring in the break-up dates and the ice season durations indicate that spring seasons are occurring earlier, and are warmer than they were in the past. The lake ice records for the decade of the 1980's was more closely examined, as this decade has been noted the warmest decade this century throughout most of Canada. Mean lake ice conditions for this period were compared to the records prior to 1973, the period upon which the mean freeze-up and break-up maps of **Figures (2) and (3)** were derived, to determine if any changes had occurred that may be related to the temperature of the region. Lakes in the Prairies and northern Ontario show a two day delay in freeze-up. Lac St. Jean showed the longest delay of approximately four days. Other lakes showed a trend to earlier freeze-up dates. Water clear of ice dates from Quebec to the Yukon have shown more substantial changes. They indicate marked changes occurring to the regional air temperature regimes during the spring season. Lake ice break-up in the 1980's seems to be taking place up to one week earlier than it did prior to 1973 at most of the selected lakes, with the exception of Knob Lake and Back Bay. The ice season durations have also decreased by about one week at most lakes, with the exception of Back Bay and Knob Lake, which show slight increases in the length of their ice seasons.

Conclusions

Satellite imagery has recently proven to be beneficial in lake ice studies. Data obtained in this manner provides near-real-

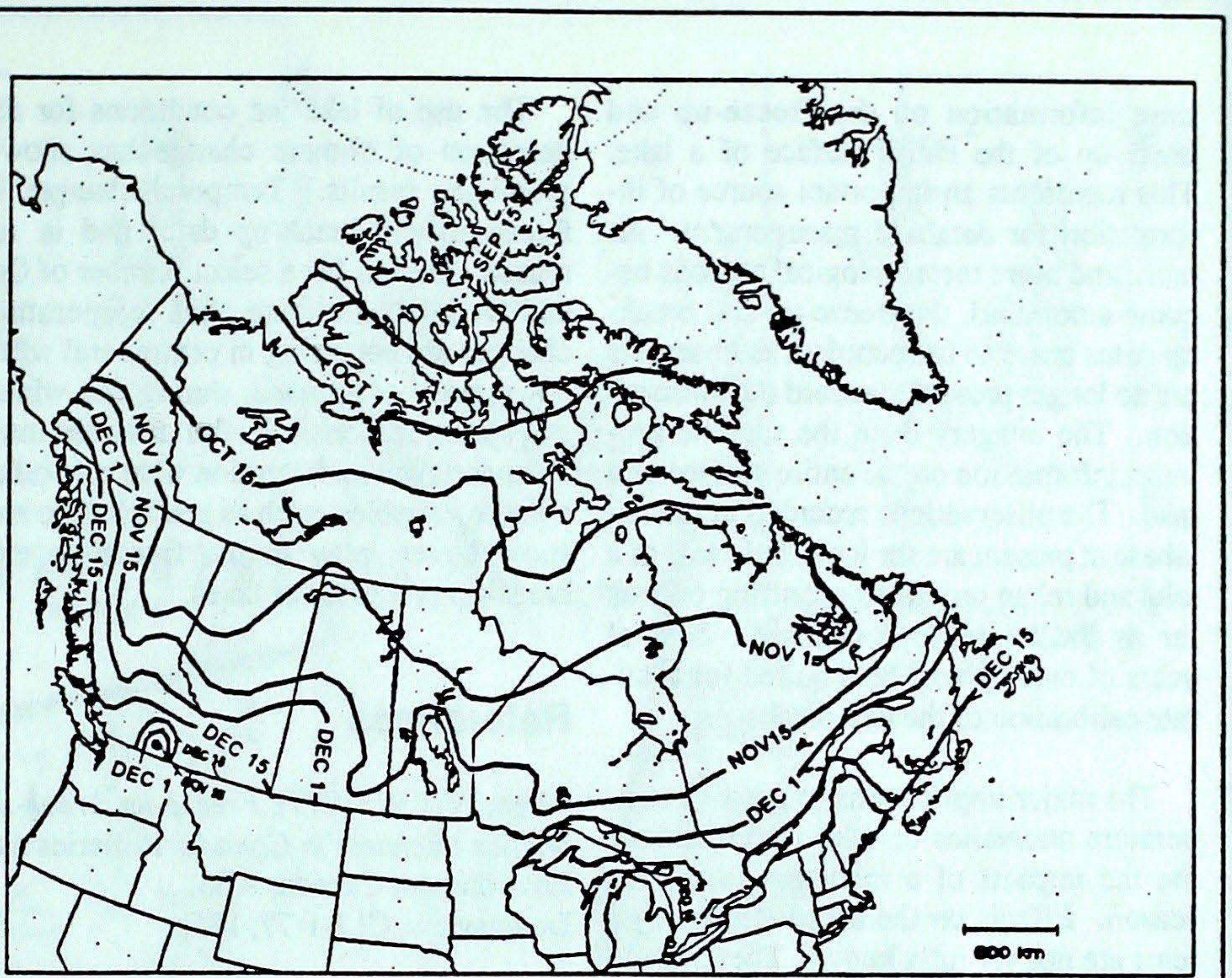

Figure 2 Mean Freeze-Up Dates (Hydrological Atlas of Canada, 1978)

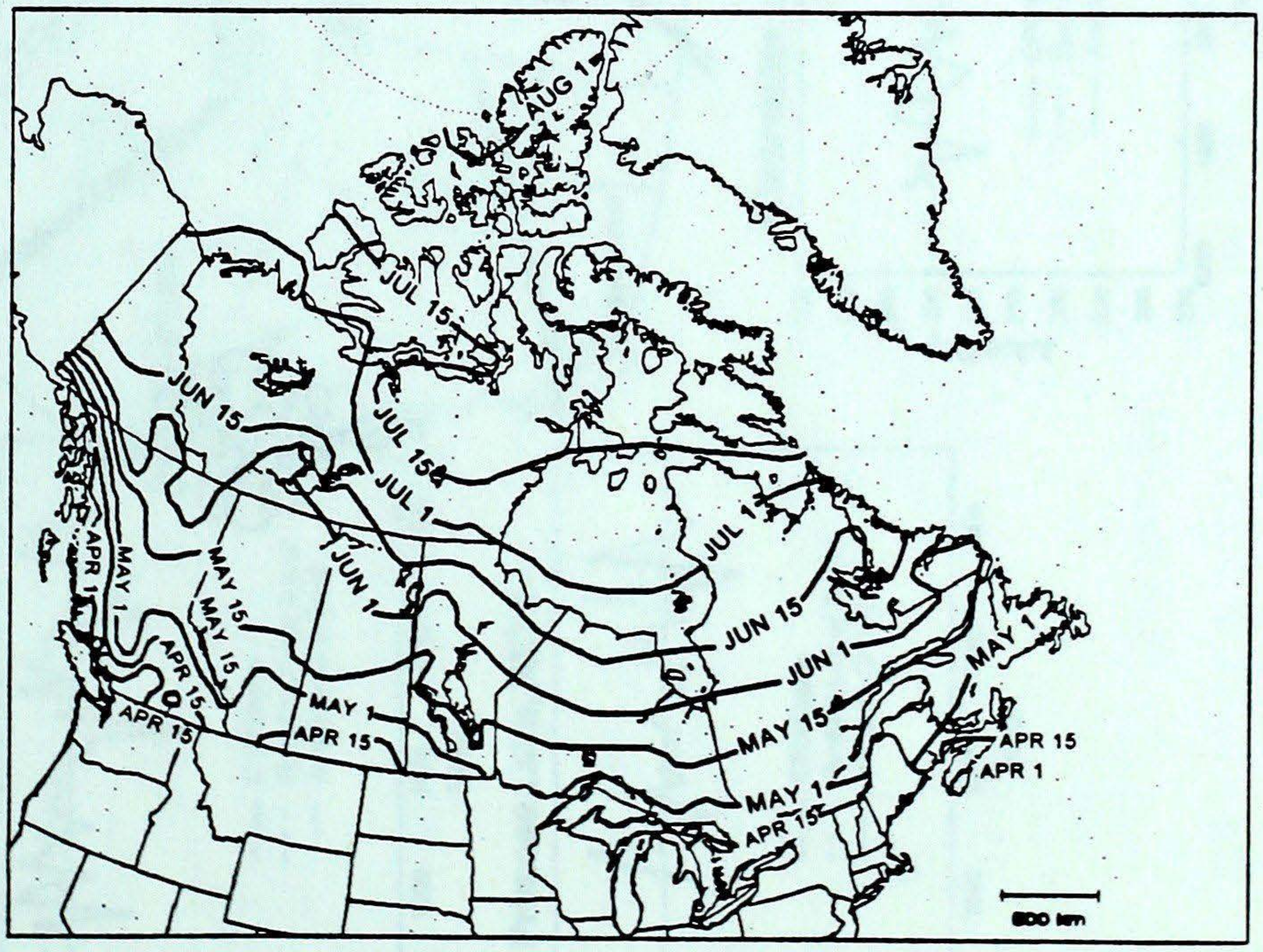

Figure 3 Mean Break-Up Dates (Hydrological Atlas of Canada, 1978)

time information on the freeze-up and break-up of the entire surface of a lake. This represents an important source of information for database management. As more and more meteorological stations become automated, the freeze-up and break-up dates cease to be recorded, as observers are no longer present to record the information. The imagery from the satellite provides information on the entire surface of a lake. The observations recorded in the database at present are for localized areas of a lake and relate processes occurring only as far as the human eye can see. Several years of overlap will be required for accurate calibration of the two databases.

The major implications of positive temperature anomalies on lake ice conditions are the impacts of a reduction in the ice season. Effects on the associated ecosystems are not yet fully known. There would be a longer shipping season, allowing increased passage of goods and services. Communities that are dependent on ice roads formed on frozen lakes will be effected by a shorter season that these roads may be utilized. Commercial fishing operations would have a longer season.

The use of lake ice conditions for the detection of climate change has shown promising results. Temporal changes in freeze-up and break-up dates and in ice season duration for a select number of Canadian lakes indicate that temperature changes are occurring in central and western regions of Canada, during the winter and spring seasons. Further analyses must be undertaken to determine what role other climate variables, such as precipitation and snow cover, play in the freeze-up and break-up processes of lakes.

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Figure 4 Time Series of Complete Freeze Over Dates

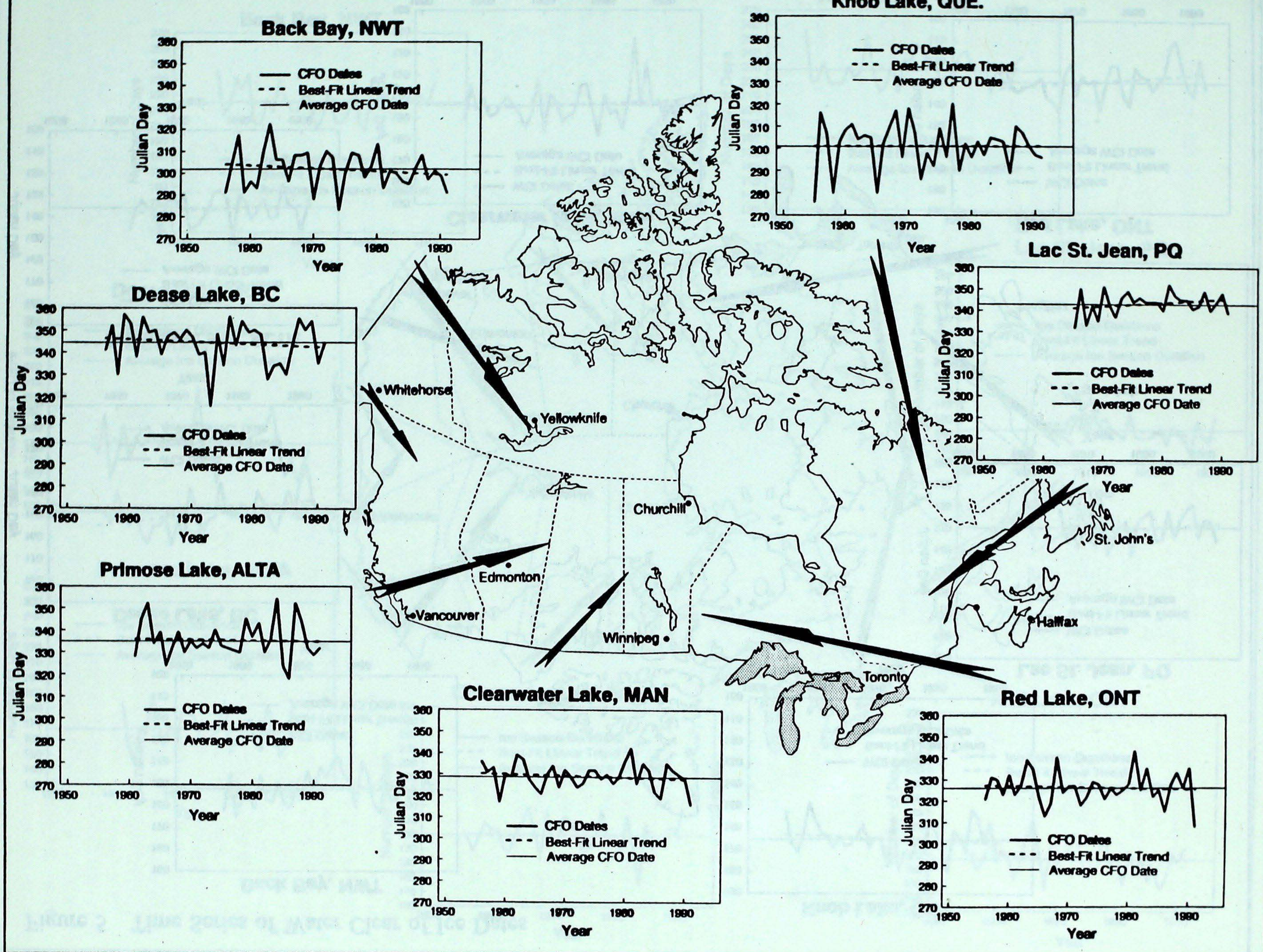


Figure 5 Time Series of Water Clear of Ice Dates

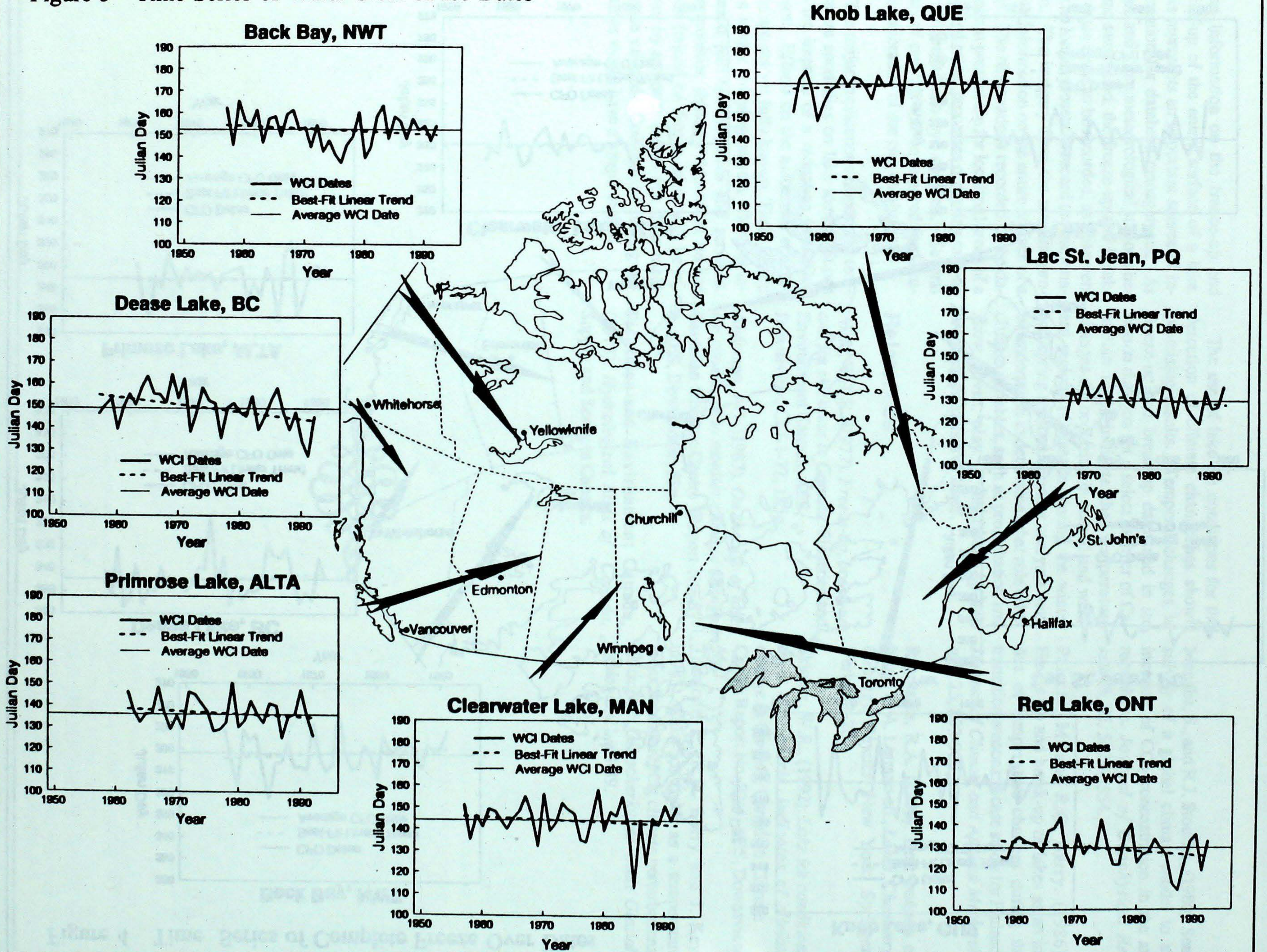
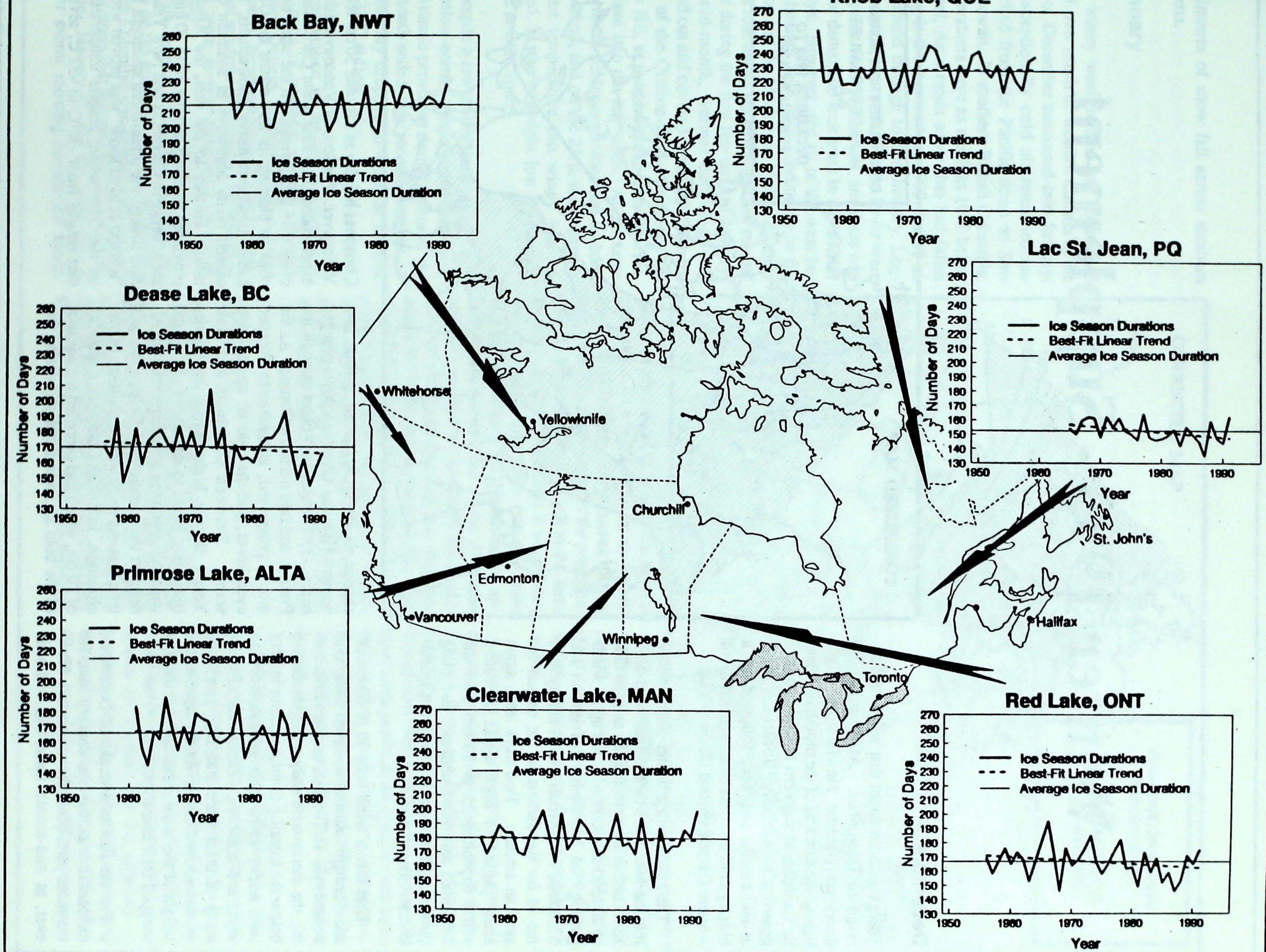


Figure 6 Time Series of Ice Season Durations

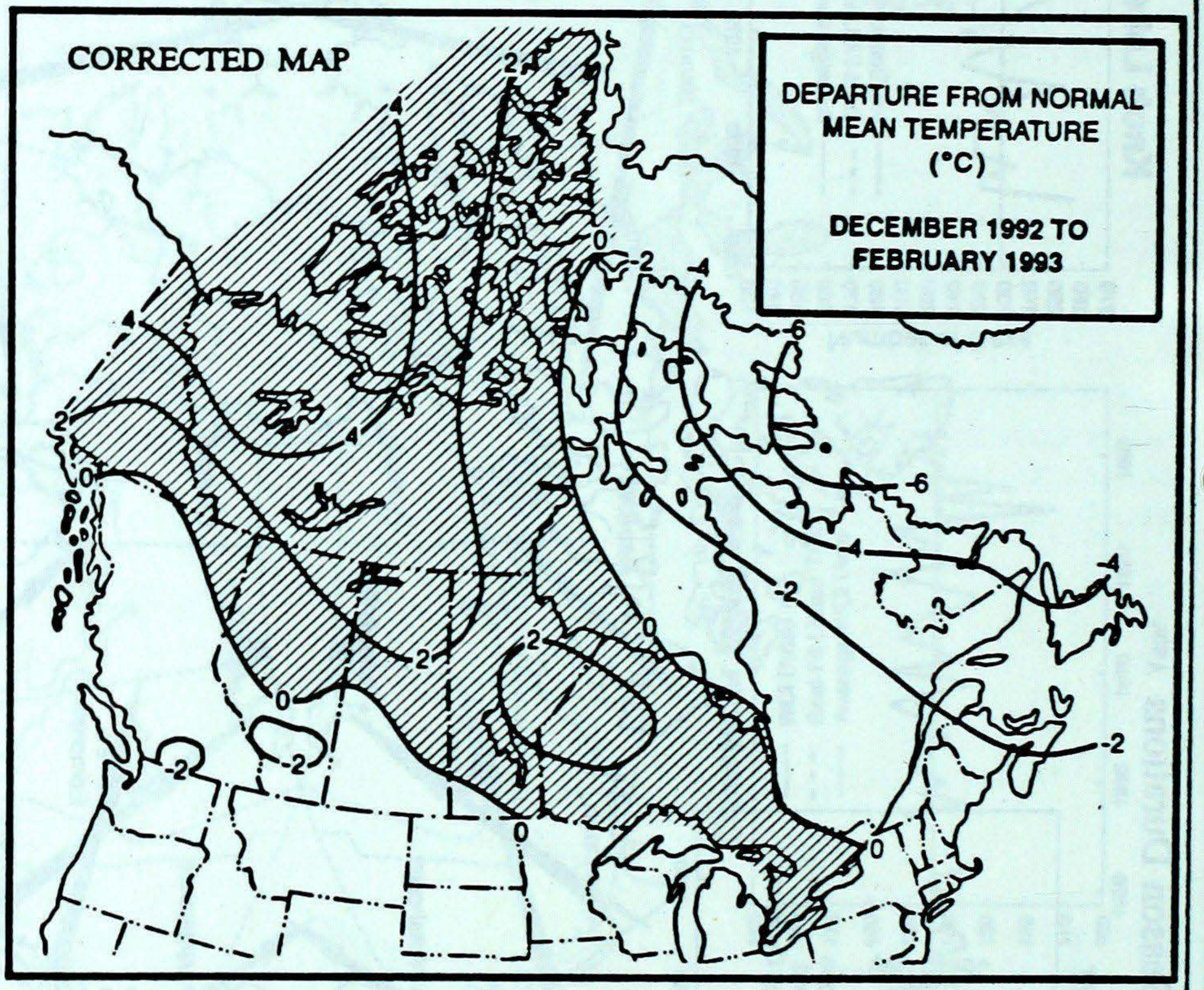


Winter 1993 - Supplement

December

There was little doubt that winter had arrived in December. After unusually heavy early-season snowfalls had highlighted the first half of the month in Atlantic Canada and southern Ontario, equally generous snowfalls hit British Columbia at mid-month, and were followed by a bitterly cold air mass that engulfed all of western Canada beyond the New Year.

The month's first winter storm moved into the Maritimes on the 3rd. Near-blizzard conditions were created as snowfalls of 20 to 25 cm were whipped up by winds gusting over 100 km/h. Heaviest hit was Moncton, which received 38 cm, tying a record for the earliest in the season for such an amount. Two days later, again accompanied by high winds, a second storm deposited 25 to 50 cm over the Maritimes and Newfoundland, disrupting power supplies and bringing transportation services to a halt.



Less than a week later 30 to 60 cm of snow brought most of southern Ontario to a standstill. In Toronto, temperatures during the storm were only a degree or two below the freezing point, resulting in very wet, sticky snow that accumulated on wires and branches. Thousands of trees, many of them more than fifty years old, were destroyed or heavily damaged as the weight of the snow either toppled them or snapped their branches.

For the first two weeks of December, temperatures across the country had, for the most part, been above normal. However, at mid-month there was a drastic change as frigid Arctic air spilled into western Canada. Overnight lows plunged below -35°C from the Yukon through the Prairies and into northern Ontario. As the month progressed, temperatures dropped even lower, and the cold air spread eastwards. Between Christmas and New Year's daytime highs across the Prairies frequently failed to rise above -30°C, and windchill warnings were required from Alberta to the Maritimes. Despite the cold temperatures there was no shortage of precipitation. In British Columbia, a snowfall of 20 cm, which had preceded the advance of the cold air, was surpassed during the Christmas holiday as a further 30 cm fell in Vancouver. Portions of Vancouver Island experienced their first white Christmas in more than thirty years. At the same time, cold air blasting its way across the Great Lakes produced heavy snowsqualls, and closed many highways in southern Ontario. Further to the east, the Atlantic provinces received another 30 to 50 cm of snow between Christmas and New Year's. And finally, the often-heard statement that "it's too cold to snow" was proven wrong on the 28th when, despite temperatures that ranged from -30°C to -32°C, several centimetres of snow fell across southern Alberta.

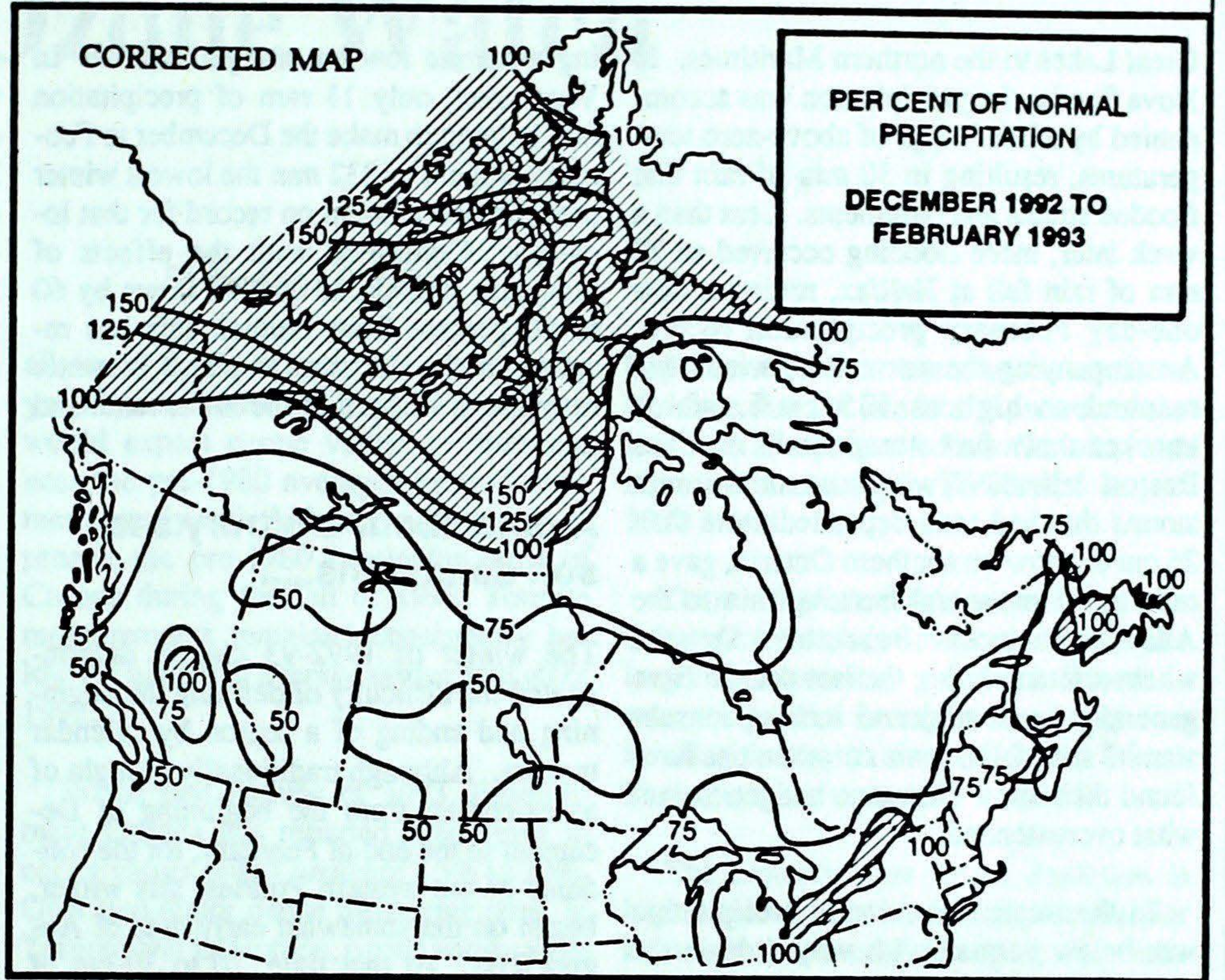
January

The wintry weather that had established itself over much of western Canada at the end of December continued into January, as exceptionally cold air remained entrenched from the Pacific coast to Saskatchewan. In southern British Columbia, temperatures were as much as 10°C below normal, As a result snow that had fallen during in the last week of 1992, stayed on the ground through to mid-January. Logging operations on the Fraser River were disrupted, water pipes froze, and there was fear of damage to fruit trees in the interior valleys. However, not all of the west began January with cold conditions; in the Yukon and the Mackenzie Valley, daytime highs rose above the freezing mark several times during the first few days of January. By mid-month, warmer conditions had spread out and covered most of the country west of the Quebec City. Numerous records fell, as temperatures across the Prairies rose into the low teens. At the same time, much colder conditions had invaded the Yukon, and on the 23rd, the country's coldest temperature this winter was recorded, as the overnight low dropped to -57°C at Old Crow.

Despite a few brief incursions of warm air, below-normal temperatures dominated the Atlantic provinces during January. As the month ended, new records were set, as the mercury dropped to -29°C at Halifax and -33°C at Deer Lake.

Precipitation in January was sparse in most parts of southern Canada, as only southern Ontario, southern Quebec, and a portion of Newfoundland received above-normal amounts of moisture. Nevertheless there were several significant storms in January.

With several centimetres of snow already on the ground, 1993 in southwestern British Columbia was greeted with another major storm that dropped as much as 25 cm on the January 4. On the same day, a major storm moving across the Great



Lakes produced copious amounts of precipitation. As a result of warm air associated with this storm, temperatures rose as high as 13°C, causing most of the precipitation, as much as 50mm, to fall in the form of rain. A little more than a week later, snowfall advisories were required from southern Ontario to the Maritimes, as another storm moving out of the American midwest resulted in significant accumulations of snow and freezing rain that produced ice build-ups reaching 10 mm. As the month ended, as much as 40 to 60 cm of wind-whipped snow fell across the Atlantic provinces, paralysing transportation, closing schools and businesses, and cutting off power to 10,000 people.

February

The storm that moved through Atlantic Canada during the last few days of January marked the leading edge of very cold air that covered the eastern part of the country throughout February. During the first few days of the month, overnight lows dropped to -25°C to -35°C, and windchill warnings were required from eastern Manitoba to the Maritimes. Throughout the rest of the month there was little relief from this cold. As a result, monthly means were 2 to 5 degrees below normal from Ontario eastwards.

It was a different story in the west. As the month began, abnormally warm air extending from the Pacific to Manitoba raised daytime highs into the mid-teens in British Columbia and Alberta. These mild conditions persisted for about a week and a half, before much colder air appeared, dropping overnight lows to values well below -30°C and providing a sudden end to an early spring.

Precipitation during February was notable for its abundance in the east and its scarcity in the west. Several storms moving from the American mid-west or up the Atlantic seaboard were responsible for what seemed at times to be a continuous source of moisture for the residents of southern Ontario, southern Quebec, and the Maritimes. On the 12th and 13th, 30 to 40 cm snowfalls extended from the lower

Great Lakes to the northern Maritimes. In Nova Scotia, the precipitation was accompanied by a brief surge of above-zero temperatures, resulting in 50 mm of rain that flooded streets and basements. Less than a week later, more flooding occurred as 72 mm of rain fell at Halifax, setting a new one-day February precipitation record. Accompanying the storm were winds that reached as high as 135 km/h, which knocked down fuel storage tanks on Cape Breton Island. Two more mid-month storms that had each deposited more than 25 cm of snow on southern Ontario, gave a mixture of snow and freezing rain to the Atlantic provinces. In southern Ontario, where winters during the last decade have generally been mild and lacking in substantial snowfalls, some communities have found their snow clearance budgets somewhat overextended.

In the western provinces, precipitation was below normal, with very little in the way of significant moisture since British Columbia's early January snowfalls. Soil moisture levels in the Prairie grain growing areas are low but not yet critical. In Vancouver, only 11 mm of precipitation fell, helping to make the December to February amount of 232 mm the lowest winter precipitation amount on record for that location. Combined with the effects of mountain snowpacks that are down by 60 to 80 percent from normal, this has resulted in the decision to phase in water restrictions in April in the lower mainland area

A note about arbitrary season definitions.....

The winter of 1992-93 clearly demonstrated the difficulty of defining the beginning and ending of a season by calendar months. Although traditionally thought of as extending from the beginning of December to the end of February, for the residents of the western Prairies, this winter, began on the somewhat early date of August 21st. At that time, 20 to 30 cm of snow fell, followed by a killing frost, as overnight temperatures dropped several degrees below the freezing mark. Two weeks later, the early start to winter was confirmed as another snowstorm dropped 35 cm of snow on southern Alberta. At the other end of the season, the February 28 ending date for winter was shown to be fallacious, as two major snow storms moved through the eastern Canada, in the first week of the March. By mid-March, a storm widely dubbed "the storm of the century", moved up the Atlantic seaboard, spreading precipitation as far west as Lake Huron and dropping more than 40 cm of snow from eastern Lake Ontario to the Maritimes. On the morning of the 14th, the snow depth at Ottawa stood at 135 cm higher than at any time during the station's history. Certainly, for the recipients of this storm's snow, spring would not be considered to have arrived at the end of February In the following week, Gander Newfoundland, broke its all-time record for snowfall. Winter's grip was tenacious this year.

Malcolm Geast

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Ozone Watch

□ *By Anne O'Toole*

In March 1992, "Ozone Watch" was introduced in Canada. Ozone Watch provides information on the current status of the stratospheric ozone layer over Canada. Ozone Watch acts to increase public awareness and reduce the fears that are often generated by misunderstanding. A greater understanding of the issue will likely lead to a more informed response from the public both for taking actions to protect the stratospheric ozone layer and to react wisely to increased ultraviolet levels.

Stratospheric ozone is measured with a Brewer Spectrophotometer at 12 locations across Canada. A two week average of current values is compared to the pre-1980 averages for the same time period. Pre-1980 averages were chosen to represent the natural historic level of the ozone layer. Ozone Watch provides on-going information on the normal short term variations in the ozone layer and also provides an indication of the degree of ozone depletion. Ozone Watch is issued on a weekly basis every Friday. Figure 1 shows the most recent Ozone Watch graphic that accompanies a text description. Environment Canada supplies the Ozone Watch to the media in the same manner as its regular weather reports.

Environment Canada scientists have tracked a modest, but significant thinning of the ozone layer over southern Canada over the past ten years. This depletion is greatest in the spring. Fortunately, this is at a time when the ozone layer is naturally at its thickest. Over Canada, the average ozone values reported in 1992 were, overall, lower than averages for any preceding year. From observations in past years, one would expect ozone values to return to near the pre-1980 averages by mid-summer or early fall. Although values did approach the pre-1980 levels for most of Canada during the fall of 1992, Toronto measurements remained consistently below the historical average throughout all of 1992.

In the first months of 1993, Environment Canada has reported a decrease in ozone values over Canada of 15% to 20%. Over two major ozone measuring sites, in Toronto and Edmonton, ozone values were unusually low. Ozone values over Edmonton fell to an average of 25% below the pre-1980 normal during a two week period, ending February 12. This value is the largest winter difference recorded in southern Canada over the 30 years of record. The lowest previous value for Edmonton was 21% below normal (reported in December 1985).

Record lows for the season were also observed over Toronto, when ozone values dipped to an average of 21% below normal for four weeks in January and February. In March, the pattern continued, with record low individual ozone measurements, and two week average differences as large as 23% below. Over Toronto, the previous low records were 17% below normal for the month of January (reported in 1985) and 20% below for February (reported in 1989).

It is noteworth, is that previous records were more isolated and did not persist for such an extended period of time. Measurements taken at Goose Bay, Labrador, indicated that ozone loss was not as severe, reaching a low of 16% in February. In the high Arctic, first measurements from Resolute Bay, in late March, were consistent with the pattern across Canada, with reports of ozone depths 26% below its pre-1980 levels.

Ozone depletion this summer will be less severe than it is now, but will likely be larger than previous summers. Based on recent data, the average ozone depletion for May to August over Canada will most likely be in the range of 5% to 10%.

The concern over ozone depletion is high, mainly because of the potential for increased amounts of damaging ultraviolet rays from the sun. The most recent scientific information indicates that for every 1% decrease in ozone one would expect a 1.1% to 1.4% increase in UV-B. UV rays occur naturally and exposure to UV has always been a health concern. Excessive exposure to the sun's ultraviolet rays leads to sunburn and, in some cases, can lead to skin cancer and eye cataracts. Health authorities recommend sun-smart action: limit time spent in the midday sun when UV is strongest, wear a hat and other protective clothing, and sunglasses which are UV-rated, and use a sunscreen.

The reduced ozone this spring has produced UV values in March which are more typical of mid-May. UV Index values were around 6, in late March, in Central and Eastern Canada. Normal values for this time of year are usually near 4. Ultraviolet intensities at this time of year are lower than in summer because of the low sun angles. For comparison purposes, UV Index values on sunny days in the summer in the same regions of Canada are usually near 8.

With the expected lower ozone this summer , UV values may increase by 6% to 12%. This is equivalent to moving south by approximately 700 km. In the Arctic, UV values remain low throughout the year, as the sun's rays are naturally weaker. (But reflections from snow or ice gradually increases exposure)

The long-term loss of ozone can be attributed to the build-up of industrial chemicals in the atmosphere, most notably, CFC's (chlorofluorocarbons). However, natural phenomena such as volcanic eruptions and variations in the weather patterns, can temporarily affect the thickness of the ozone layer. Unusual weather conditions, such as those that gave rise to higher temperatures in Edmonton during February, can contribute to record low ozone values. Volcanic debris from Mount Pinatu,bo, which erupted in the Philippines in 1991 may have also influenced ozone levels. Debris from major volcanic eruptions can remain in the upper atmosphere for two to three years.

It is important to reduce the man-made contributions to low ozone values. Canada played an active role at the 1992 international conference in Copenhagen, where the Montreal Protocol - a global agreement to protect the ozone layer - was significantly strengthened. The agreement reached at Copenhagen calls for the production and consumption of CFCs to be phased out by January 1, 1996. Even with the most stringent controls, ozone depleting substances now in the environment will reach the stratosphere in the next few years, leading to peak stratospheric chlorine levels around the year 2000.

With the weekly Ozone Watch and the daily UV Index forecasts, Canadians can stay aware of these important environmental changes over the coming years.

Ozone destroying chlorine existed longer in 1992-93 winter

□ *By James Wilson,*
Jet Propulsion Laboratory, Pasadena, California

Ozone-destroying forms of chlorine existed for much longer in the Arctic stratosphere this winter than last, say scientists.

Northern Hemisphere ozone abundance also was observed to be some 10 percent below that measured during the same period last year, with some regions 20 percent lower.

Using NASA's Upper Atmosphere Research Satellite (UARS), Dr. Joe Waters and his colleagues at the Jet Propulsion Laboratory (JPL), Pasadena, Calif., and Edinburgh University, Scotland, have collected daily maps of ozone and other gases, and of temperature in different layers of the stratosphere. One of their most critical measurements is of chlorine monoxide, a form of chlorine that destroys ozone. They reported the results in the international scientific journal Nature.

"Ozone concentrations in the Arctic in a layer about 12 miles (20 kilometers) high, where most chlorine monoxide was located, decreased by 0.7 percent per day from mid-February through early March 1993," Waters said. Ozone levels normally increase in this area at this time of the year, he added.

Chlorine already in the stratosphere, from chlorofluorocarbons, is converted to ozone-destroying forms by chemistry occurring on clouds which form at low temperature.

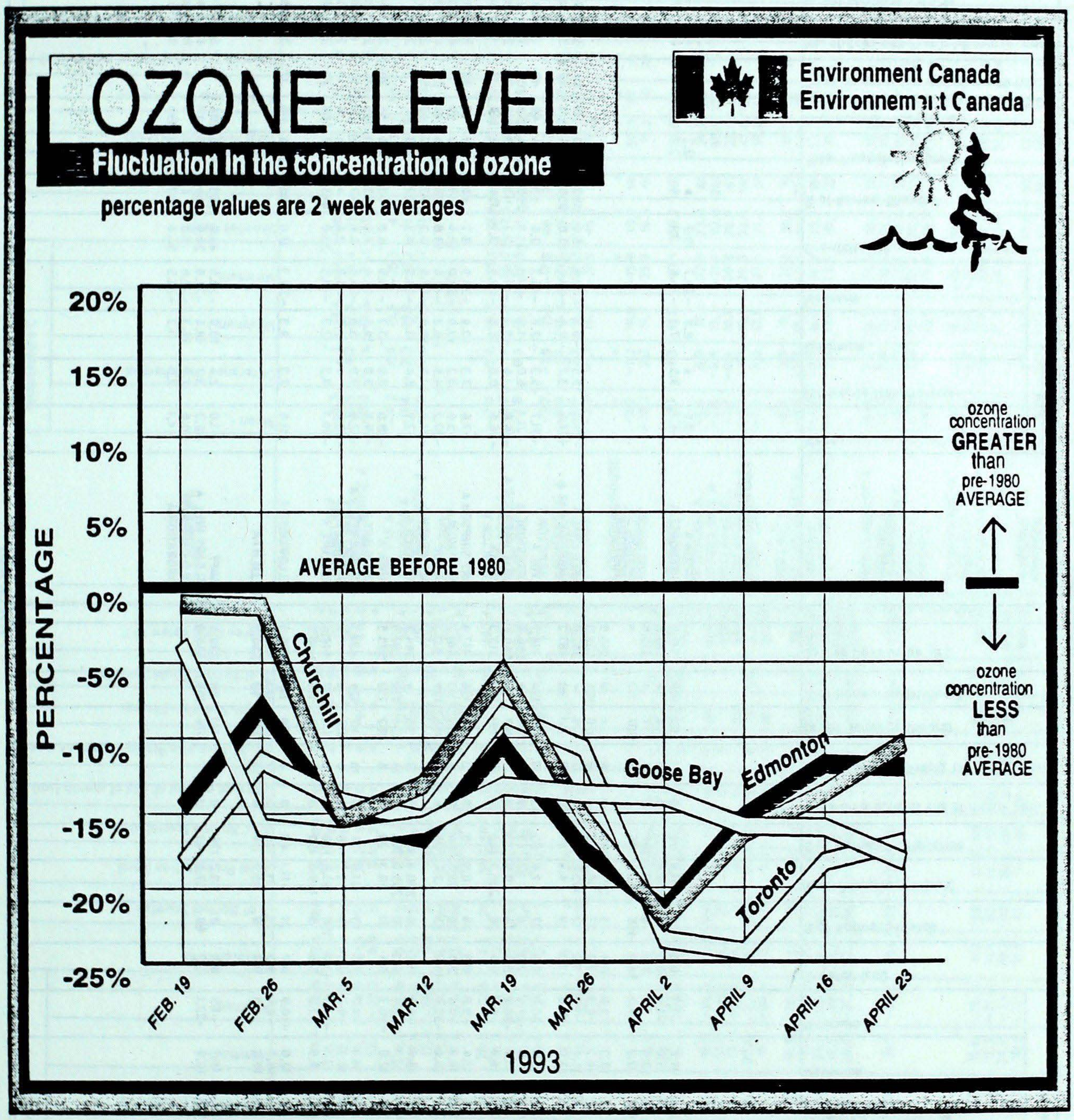
Last year, the scientists measured large abundances of chlorine monoxide in the Arctic, but the concentrations decreased after the stratosphere warmed in late January. This winter, the stratosphere remained cold through February, and chlorine monoxide remained abundant through early March.

About as much chlorine monoxide was seen in the northern polar regions in February 1993 as was measured at the South Pole, before the 1992 Antarctic ozone hole formed.

"We do not see a well-defined area of ozone loss that could be described as an Arctic ozone hole," Waters said, "but the smaller abundances of ozone seen throughout the Northern Hemisphere this winter raise the question of whether the chlorine destruction of ozone has been spread over a wider area." Record low values of ozone also have been reported recently by the World Meteorological Organization and Environment Canada.

The microwave limb sounder aboard UARS was developed and is operated by JPL, led by Waters and sponsored by NASA's Office of Mission to Planet Earth. Additional members are from Edinburgh University, Heriot-Watt University and the Rutherford-Appleton Laboratory in the United Kingdom.

UARS, launched Sept. 12, 1991, aboard Space Shuttle Discovery, is managed by NASA's Goddard Space-Flight Center, Greenbelt, Md.


OZONE LEVEL
Fluctuation in the concentration of ozone
percentage values are 2 week averages
Environment Canada
Environnement Canada
20%
15%
10%
5%
0%
-5%
-10%
-15%
-20%
-25%
PERCENTAGE
AVERAGE BEFORE 1980
Churchill
Goose Bay
Edmonton
Toronto
FEB. 19
FEB. 26
MAR. 5
MAR. 12
MAR. 19
MAR. 26
APRIL 2
APRIL 9
APRIL 16
APRIL 23
1993
ozone concentration GREATER than pre-1980 AVERAGE
ozone concentration LESS than pre-1980 AVERAGE

MARCH 1993

STATION	Temperature C				Snowfall (cm)	% of Normal Snowfall	Total Precipitation (mm)	% of Normal Precipitation	Snow on ground at end of month (cm)	No. of days with Precip 1.0 mm or more	Bright Sunshine (hours)	% of Normal Bright Sunshine	Degree Days below 18 C
	Mean	Difference from Normal	Maximum	Minimum									
BRITISH COLUMBIA													
ABBOTSFORD A	7.9	2.3	17.6	-1.3	0.0	0	161.9	116	0	13	121	108	312.9
ALERT BAY	6.3	1.1	13.6	-1.4	0.0	0	200.4	163	0	15	*	*	362.8
AMPHITRITE POINT	7.8	1.6	13.8	1.8	0.0	0	362.9	106	0	17	*	*	315.6
BLUE RIVER A	-1.0	0.0	12.2	-19.6	54.8	148	92.5	136	4	12	107	112	*
CAPE SCOTT	6.9	1.5	13.3	2.0	0.4	3	227.7	83	0	18	*	*	345.5
CASTLEGAR A	3.9	0.9	16.2	-8.3	7.5	27	56.7	100	0	8	128	104	437.8
COMOX A	6.6	1.6	17.4	-1.5	1.2	12	125.8	113	0	12	139	*	352.0
CRANBROOK A	2.3	1.5	13.8	-11.8	1.3	9	4.9	29	0	2	161	98	487.2
DEASE LAKE	-5.2	2.2	8.4	-30.0	9.8	37	7.4	33	43	3	178	134	718.7
FORT NELSON A	-3.2	6.6	10.8	-24.6	2.3	8	1.7	7	9	1	204	*	656.4
FORT ST JOHN A	-0.4	6.2	11.7	-20.8	8.6	26	9.8	33	0	3	167	*	569.4
HOPE A	7.9	2.3	16.7	-0.2	4.4	28	235.2	160	0	13	101	100	313.3
KAMLOOPS A	4.5	1.0	17.4	-9.8	0.9	20	0.9	9	0	0	184	126	417.9
KELOWNA A	3.1	0.5	16.2	-7.9	2.4	38	10.0	50	0	4	152	113	461.2
MACKENZIE A	-1.4	3.0	10.6	-25.0	14.0	33	43.4	88	4	9	168	134	611.2
PORT ALBERNI A	6.9	1.8	15.6	-4.6	1.0	8	300.9	140	0	17	95	*	344.7
PORT HARDY A	5.5	1.1	12.1	-2.4	0.0	0	235.0	166	0	14	134	132	387.9
PRINCE GEORGE A	0.8	2.6	12.8	-20.3	9.4	31	10.3	28	0	5	182	132	535.5
PRINCE RUPERT A	4.0	0.9	14.1	-4.7	3.4	13	141.8	74	0	16	117	124	434.1
PRINCETON A	3.1	2.1	16.2	-9.4	2.5	19	9.2	48	0	4	170	*	*
REVELSTOKE A	1.4	0.6	13.1	-10.5	47.0	150	95.8	138	11	9	119	117	514.4
SANDSPIT A	4.5	0.6	9.9	-2.2	0.6	5	149.0	150	0	16	139	115	418.5
SMITHERS A	1.0	2.3	12.0	-10.9	4.7	21	11.1	43	0	4	179	147	526.5
TERRACE A	2.8	1.3	13.5	-6.6	9.5	21	121.2	146	0	12	139	127	470.5
VANCOUVER INT'L A	7.4	1.6	16.0	-1.0	0.0	0	115.2	114	0	13	120	93	330.8
VICTORIA INT'L A	7.1	1.4	14.7	-1.5	0.0	0	99.2	138	0	13	141	98	339.4
WILLIAMS LAKE A	-0.1	0.9	10.9	-22.1	15.2	69	19.5	87	1	7	176	108	559.0

STATION	Temperature C				Snowfall (cm)	% of Normal Snowfall	Total Precipitation (mm)	% of Normal Precipitation	Snow on ground at end of month (cm)	No. of days with Precip 1.0 mm or more	Bright Sunshine (hours)	% of Normal Bright Sunshine	Degree Days below 18 C
	Mean	Difference from Normal	Maximum	Minimum									
YUKON TERRITORY													
DAWSON A	-9.5	*	8.8	-33.7	19.2	*	12.2	*	*	*	*	*	*
WHITEHORSE A	-4.7	3.5	7.3	-26.6	3.1	19	2.2	16	0	0	175	114	704.5
NORTHWEST TERRITORIES													
BAKER LAKE A	-25.4	2.5	-0.5	-40.6	16.0	193	16.0	211	84	5	170	90	1347.2
CAMBRIDGE BAY A	-27.6	3.7	-9.4	-40.4	13.8	256	9.8	209	49	3	142	77	1413.0
CLYDE A	-31.7	-5.3	-12.8	-45.2	2.6	43	2.4	40	49	1	193	120	1539.0
COPPERMINE A	-21.1	6.0	-1.8	-41.1	31.0	298	25.4	259	100	7	125	77	1213.9
CORAL HARBOUR A	-26.8	-1.6	-8.7	-41.7	12.2	113	11.8	109	29	2	187	94	1390.7
EUREKA	-36.6	0.8	-18.8	-48.9	3.7	154	3.7	168	17	1	68	57	1691.7
FORT SIMPSON A	-7.6	7.3	10.9	-25.5	9.7	46	8.8	47	28	3	183	114	792.1
FORT SMITH A	-5.6	9.2	13.0	-30.0	10.9	69	9.9	69	1	4	202	114	731.3
IQALUIT	-27.2	-4.5	-8.3	-42.6	13.8	55	10.6	45	24	4	197	112	1401.6
HALL BEACH A	-31.4	-1.9	-10.9	-48.5	5.2	42	5.0	43	50	2	*	*	1532.1
HAY RIVER A	-7.9	8.4	11.3	-31.0	4.3	22	4.0	22	6	2	*	*	800.4
INUVIK A	-18.0	7.0	-3.2	-31.9	8.0	53	6.6	55	70	2	154	89	1116.8
MOULD BAY A	-29.8	3.0	-16.5	-42.4	4.6	153	3.8	158	14	2	98	89	1481.9
NORMAN WELLS A	-12.8	7.0	5.8	-25.8	6.4	47	4.0	31	14	1	161	96	954.1
POND INLET A	-33.6	*	-12.0	-45.8	2.4	*	*	*	15	2	210	*	1598.7
RESOLUTE A	-30.1	1.3	-12.3	-41.9	20.0	645	17.7	590	20	2	86	59	1491.3
YELLOWKNIFE A	-11.6	7.3	9.3	-33.3	17.0	118	14.4	116	17	3	185	95	917.4
ALBERTA													
BANFF	-1.0	2.4	13.0	-25.5	45.4	183	42.6	204	0	6	*	*	589.2
CALGARY INT'L A	-0.3	3.7	18.6	-24.9	26.6	134	17.8	111	2	4	145	90	567.0
COLD LAKE A	-0.6	7.0	16.3	-22.6	0.8	4	0.4	2	0	0	189	110	576.5
CORONATION A	-4.1	3.0	11.2	-26.5	56.6	242	40.6	196	7	9	163	89	685.1

MARCH 1993

STATION	Temperature C: Mean	Difference from Normal	Maximum	Minimum	Snowfall (cm)	% of Normal Snowfall	Total Precipitation (mm)	% of Normal Precipitation	Snow on ground at end of month (cm)	No. of days with Precip 1.0 mm or more	Bright Sunshine (hours)	% of Normal Bright Sunshine	Degree Days below 18 C
EDMONTON INT'L A	-3.1	3.6	11.9	-26.8	33.4	180	28.7	179	0	5	171	99	653.3
EDMONTON MUNICIPAL	-0.7	4.3	13.4	-20.0	16.4	*	15.4	83	0	4	166	99	577.6
EDMONTON NAMAO A	-0.9	4.7	12.6	-21.5	17.0	98	14.7	82	0	3	*	*	584.7
EDSON A	-1.9	2.8	16.5	-29.0	21.4	66	22.2	97	0	6	142	92	616.0
FORT CHIPEWYAN A	-8.1	4.7	13.5	-32.5	6.0	36	6.6	36	*	*	*	*	*
FORT MCMURRAY A	-1.1	8.1	15.3	-26.8	5.0	21	4.0	19	0	1	212	128	591.4
GRANDE PRAIRIE A	-0.9	6.3	12.6	-25.4	8.3	36	9.0	43	0	4	181	*	586.7
HIGH LEVEL A	-3.2	7.8	12.3	-28.4	7.8	37	7.4	38	0	2	194	111	655.4
JASPER	-1.3	1.4	11.2	-26.1	24.4	166	26.8	167	0	10	180	*	600.1
LETHBRIDGE A	2.3	4.4	17.5	-20.8	23.8	90	20.8	86	0	4	162	97	487.8
MEDICINE HAT A	2.1	4.9	20.5	-21.5	4.4	24	37.3	202	0	6	172	106	493.4
PEACE RIVER A	-0.9	7.6	14.0	-21.8	0.2	1	2.3	13	0	1	*	*	584.1
RED DEER A	-2.7	3.5	16.6	-26.1	27.3	135	25.4	130	2	6	*	*	639.6
ROCKY MTN HOUSE A	-2.8	1.8	14.0	-29.5	43.6	145	27.4	103	19	7	*	*	645.6
SLAVE LAKE A	1.1	7.4	13.0	-21.5	2.0	7	1.4	7	0	0	184	110	578.7
SUFFIELD A	1.0	*	19.9	-24.0	12.4	*	31.9	*	0	5	178	*	526.3
WHITECOURT A	-1.2	4.7	11.7	-23.3	16.6	65	15.2	63	0	4	*	*	594.9
SASKATCHEWAN													
BROADVIEW	-2.6	5.5	19.5	-25.1	44.2	250	45.0	281	17	5	203	117	638.1
CREE LAKE	-6.5	7.0	13.0	-34.0	16.8	80	10.6	73	6	4	210	117	758.6
ESTEVAN A	-2.2	3.7	19.7	-28.3	22.0	127	43.6	226	0	6	176	95	622.2
KINDERSLEY	-3.2	3.4	15.5	-24.0	15.2	104	23.6	161	0	7	150	*	656.4
LA RONGE A	-3.4	7.3	13.9	-27.1	4.8	22	4.2	23	0	1	*	*	655.6
MEADOW LAKE A	-0.8	*	17.5	-22.5	0.0	*	0.0	*	0	*	202	*	580.1
MOOSE JAW A	-0.7	4.9	23.0	-23.8	38.3	207	41.5	237	10	9	167	100	578.1
NIPAWIN A	-3.7	*	15.1	-24.5	2.2	*	5.4	*	0	3	183	*	672.2
NORTH BATTLEFORD A	-1.0	7.6	16.6	-20.6	1.6	8	2.4	12	0	0	*	*	588.1
PRINCE ALBERT A	-1.5	8.8	18.0	-22.1	2.0	10	2.8	15	0	1	186	113	604.2
REGINA A	-2.3	5.5	21.6	-28.2	34.2	187	33.6	189	12	6	163	105	629.5
SASKATOON A	-1.3	7.3	18.9	-20.1	4.6	25	16.4	89	0	4	*	*	598.5
SWIFT CURRENT A	1.7	7.4	20.0	-25.0	22.6	106	38.2	190	0	7	158	100	608.9
YORKTON A	-2.1	7.5	21.1	-21.8	8.6	33	19.4	74	3	5	182	109	621.9
MANITOBA													
BRANDON A	-4.2	4.5	15.8	-26.8	11.6	59	12.0	60	0	4	188	*	722.1
CHURCHILL A	-18.2	2.2	8.3	-37.0	15.8	85	10.0	55	10	2	201	106	1121.3
DAUPHIN A	-2.6	6.5	24.2	-23.1	28.5	117	26.5	108	9	4	182	103	636.6
GILLAM A	-14.2	2.3	10.1	-32.5	17.8	57	7.8	40	16	2	*	*	996.4
ISLAND LAKE	-9.3	2.7	14.1	-32.2	20.2	36	16.4	53	8	5	*	*	844.8
LYNN LAKE A	-10.5	4.2	12.4	-36.4	21.6	87	18.6	122	15	5	186	100	883.5
NORWAY HOUSE A	-8.2	*	10.3	-34.1	23.6	*	15.2	*	0	5	*	*	819.1
THE PAS A	-4.3	6.9	15.6	-25.5	4.2	15	13.1	56	*	1	201	115	693.7
THOMPSON A	-11.4	2.8	13.7	-37.2	21.3	73	19.9	96	6	3	182	93	909.8
WINNIPEG INT'L A	-5.5	2.7	7.8	-25.1	11.0	52	9.7	43	0	3	167	95	728.6
ONTARIO													
EARLTON A	-7.0	0.6	16.8	-29.1	18.7	42	17.6	30	2	6	*	*	776.3
GERALDTON A	-8.2	*	15.8	-36.0	17.0	*	18.4	*	9	7	*	*	812.0
GORE BAY A	-3.8	0.5	16.2	-23.5	11.8	38	15.2	28	4	4	*	*	675.0
HAMILTON A	-2.7	-1.9	15.1	-17.8	46.6	232	63.3	82	*	9	*	*	640.9
KAPUSKASING A	-8.0	1.4	15.2	-31.5	15.6	33	14.7	27	17	3	*	*	806.8
KENORA A	-4.4	2.7	11.5	-25.3	12.0	41	11.3	38	3	3	*	*	692.8
KINGSTON A	-2.7	-1.1	14.3	-21.9	45.8	141	65.8	77	*	10	114	81	648.3
LANSDOWNE HOUSE	*	*	*	*	*	*	*	*	*	*	*	*	*
LONDON A	-2.2	-1.3	18.0	-15.9	39.2	141	50.3	67	0	11	85	70	625.1
MOOSONEE	-10.1	2.2	14.7	-35.3	16.6	50	15.2	41	28	4	170	115	870.7
MUSKOKA A	-5.1	-1.3	17.8	-27.1	38.7	105	39.8	60	4	8	*	*	682.4
NORTH BAY A	-4.4	0.9	19.1	-22.9	33.8	88	24.7	40	8	7	147	98	694.8
OTTAWA INT'L A	-3.6	-0.6	15.3	-21.9	92.8	260	86.5	128	5	10	157	106	670.0
PETAWAWA A	-4.7	-0.4	18.8	-30.8	28.0	93	25.5	39	2	8	*	*	701.7
PETERBOROUGH A	-4.2	-1.7	16.9	-28.3	33.8	145	41.8	58	*	10	*	*	688.9
PICKLE LAKE	-7.4	3.3	12.8	-27.6	21.4	56	18.6	44	3	6	*	*	787.7
RED LAKE A	-6.4	2.3	11.1	-30.1	18.7	78	16.3	57	16	6	156	*	756.6
ST CATHARINES A	-1.7	-2.8	16.0	-21.1	41.0	229	55.0	67	*	13	97	*	609.5
SARNIA A	-1.9	-2.2	12.4	-14.6	33.2	151	53.0	79	*	11	85	67	617.9
SAULT STE MARIE A	-4.2	0.7	13.8	-23.5	10.7	35	12.3	21	1	3	175	116	686.8
SIOUX LOOKOUT A	-4.8	3.5	14.0	-31.6	18.7	58	18.5	53	5	5	*	*	737.3
SUDBURY A	-5.1	0.9	15.3	-22.5	21.6	62	23.0	42	2	5	168	110	715.8
THUNDER BAY A	-5.1	1.2	11.0	-23.7	19.8	58	13.4	30	2	4	169	98	717.0
TIMMINS A	-7.1	1.3	16.3	-28.4	20.6	38	20.5	35	24	4	*	*	776.5
TORONTO	-0.1	*	15.6	-15.0	28.2	*	44.4	*	0	9	*	*	558.3
TORONTO INT'L A	-2.1	-1.1	16.5	-18.8	28.0	126	31.0	51	*	8	*	*	621.2
TRENTON A	-2.9	-1.9	15.8	-21.9	24.2	91	47.2	66	*	10	*	*	648.6
WATERLOO WELLINGTON	-3.3	-1.4	17.4	-22.8	40.0	165	38.8	47	0	9	*	*	659.7
WAWA A	-7.2	*	14.3	-29.5	35.0	*	24.4	*	44	6	*	*	779.7
WIARTON A	-4.5	-1.7	11.4	-21.8	40.8	95	42.4	65	3	10	131	95	679.6
WINDSOR A	0.2	-1.0	17.9	-13.4	42.3	211	68.7	96	0	9	*	*	552.6

MARCH 1993

STATION	Temperature C Mean	Difference from Normal	Maximum	Minimum	Snowfall (cm)	% of Normal Snowfall	Total Precipitation (mm)	% of Normal Precipitation	Snow on ground at end of month (cm)	No. of days with Precip 1.0 mm or more	Bright Sunshine (hours)	% of Normal Bright Sunshine	Degree Days below 18 C
QUEBEC													
BAGOTVILLE A	-7.1	-0.6	15.0	-26.5	28.8	60	36.3	70	10	7	*	*	776.9
BAIE COMEAU A	-7.8	-1.1	10.3	-28.1	45.2	75	39.0	50	32	6	213	142	797.6
BLANC SABLON A	-10.2	-4.4	5.9	-24.7	87.8	106	90.4	80	34	13	131	*	873.1
CHIBOUGAMAU CHAPAIS	-10.1	*	14.0	-35.7	*	*	20.6	*	0	3	*	*	870.6
GASPE A	-7.4	*	15.2	-28.6	79.0	*	51.8	*	20	6	151	*	786.4
INUKJUAK A	-22.3	-1.7	-0.9	-35.1	5.4	60	3.6	40	26	1	214	134	1247.0
KUUJJUAQ A	-20.5	-2.8	-0.7	-37.2	19.6	73	19.2	74	30	7	186	113	1191.8
KUUJJUARAPIK A	-17.3	-0.2	5.1	-36.9	6.8	34	6.2	30	8	2	162	96	1095.1
LA GRANDE IV A	-15.7	*	7.3	-41.4	12.0	*	10.6	*	18	3	199	*	1046.2
LA GRANDE RIVIERE A	-13.9	*	7.0	-35.4	19.0	*	19.0	*	38	4	167	*	990.4
MANIWAKI	-5.2	-0.1	18.9	-28.9	39.6	117	36.6	71	22	10	164	113	718.7
MONT JOLI A	-6.3	-1.3	12.1	-20.9	69.0	109	65.0	90	13	6	187	144	753.3
MONTREAL INT'L A	-4.0	-1.5	14.0	-23.9	69.2	194	70.0	95	0	11	164	106	682.9
NATASHQUAN A	-10.2	-4.0	3.7	-28.2	66.6	116	60.8	75	52	11	164	116	874.8
QUEBEC A	-5.8	-1.3	12.2	-23.6	58.4	108	51.6	63	36	9	177	126	736.6
ROBERVAL A	-7.4	-0.5	15.3	-30.5	36.6	62	36.6	60	0	8	200	*	789.2
SCHEFFERVILLE A	-18.1	-3.0	5.1	-38.6	8.6	21	7.8	19	45	2	205	125	1120.5
SEPT-ILES A	-9.2	-2.6	9.2	-28.8	56.2	80	53.6	65	25	5	195	127	841.7
SHERBROOKE A	-5.1	-1.1	19.9	-29.1	77.4	145	77.4	97	12	12	144	*	716.4
ST HUBERT A	-4.4	-2.0	13.5	-21.7	59.8	*	63.6	80	4	12	159	*	694.6
VAL D'OR A	-7.6	0.7	15.2	-29.6	29.2	61	26.6	45	8	6	196	126	794.4
NEW BRUNSWICK													
CHARLO A	-6.3	-0.8	17.2	-26.1	75.0	99	52.2	57	44	7	186	126	745.4
FREDERICTON A	-3.9	-1.5	19.1	-25.1	72.0	148	78.1	92	7	7	*	*	692.1
MONCTON A	-4.6	-1.7	17.1	-22.3	105.4	156	111.4	99	0	7	162	117	699.0
SAINT JOHN A	-4.0	-1.5	16.7	-22.6	79.6	160	93.8	82	2	10	163	113	680.0
NOVA SCOTIA													
GREENWOOD A	-2.6	-1.7	17.3	-20.7	118.6	247	107.2	127	0	9	*	*	637.4
HALIFAX INT'L A	-2.3	-0.7	18.0	-18.8	98.6	217	189.4	148	0	9	0	*	627.3
SABLE ISLAND	1.1	0.4	13.7	-7.9	12.2	43	130.8	112	0	11	121	104	524.9
SHEARWATER A	-1.9	-1.1	17.7	-16.9	96.0	247	154.7	132	0	10	160	109	617.2
SYDNEY A	-3.3	-0.8	15.7	-16.6	111.6	175	189.9	145	2	13	151	120	659.5
YARMOUTH A	-1.1	-1.4	12.9	-15.2	78.6	240	108.9	111	0	14	129	95	591.3
PRINCE EDWARD ISLAND													
CHARLOTTETOWN A	-5.1	-2.0	14.8	-18.9	114.2	185	128.6	135	13	11	*	*	716.3
NEWFOUNDLAND													
BONAVISTA	-4.3	-1.6	9.8	-14.8	95.2	243	142.2	163	7	17	*	*	691.7
BURGEO	-1.9	0.7	6.3	-15.0	40.4	85	80.1	53	14	10	*	*	682.2
CARTWRIGHT	-13.0	-4.9	8.6	-30.2	77.6	91	79.0	85	177	20	147	118	961.5
CHURCHILL FALLS A	-16.3	-3.2	7.3	-37.9	32.8	51	28.3	43	73	6	204	148	1062.5
COMFORT COVE	-6.4	-2.8	11.4	-20.5	117.1	170	125.2	125	78	15	*	*	753.8
DANIELS HARBOUR	-7.4	-2.9	7.8	-25.0	82.5	135	94.5	125	13	12	124	108	783.2
DEER LAKE A	-7.1	-2.6	11.7	-29.0	82.7	153	81.8	103	39	10	*	*	722.2
GANDER INT'L A	-6.0	-2.5	10.2	-19.6	163.8	227	169.6	154	25	14	133	128	743.7
GOOSE A	-14.1	-5.5	10.0	-33.0	120.5	162	83.8	116	46	11	187	145	996.1
MARY'S HARBOUR	-11.1	-4.6	9.4	-30.3	54.2	72	68.6	75	149	9	*	*	925.0
PORT AUX BASQUES	-4.7	-2.0	6.4	-16.3	94.7	184	106.1	101	13	11	*	*	706.3
ST ANTHONY	-9.1	-2.4	7.2	-23.0	85.2	138	87.6	84	85	14	*	*	842.1
ST JOHN'S A	-3.6	-1.3	11.1	-13.6	65.1	100	148.0	112	0	14	137	*	670.9
ST LAWRENCE	-2.9	-1.1	12.4	-13.8	30.3	68	125.3	106	1	14	*	*	643.8
STEPHENVILLE A	-5.8	-3.0	5.7	-21.7	97.4	166	111.4	137	29	14	152	*	727.4
WABUSH LAKE A	-15.3	-1.5	9.0	-36.3	22.4	*	22.0	39	18	7	197	*	1030.6

AGROCLIMATOLOGICAL STATIONS

MARCH 1993

STATION	Temperature C Mean	Difference from Normal	Maximum	Minimum	Snowfall (cm)	Total Precipitation (mm)	% of Normal Precipitation	Snow on ground at end of month (cm)	No. of days with Precip 1.0 mm or more	Bright Sunshine (hours)	Degree days above 5 C This month	Since jan. 1st
BRITISH COLUMBIA												
AGASSIZ	8.2	2.1	17.5	−0.5	11.4	205.6	140	0	16	136	100.0	155.3
SUMMERLAND	3.5	−0.2	16.0	−6.5	3.0	10.6	72	0	3	157	16.1	16.1
ALBERTA												
BEAVERLODGE	−0.6	5.5	13.5	−25.0	6.1	9.7	39	0	4	185	3.3	9.3
LACOMBE	−3.2	2.8	13.5	−25.0	19.7	16.4	86	0	5	141	2.9	2.9
SASKATCHEWAN												
INDIAN HEAD	−3.1	4.8	18.0	−28.0	39.0	47.5	218	12	9	**	7.3	10.3
MELFORT	−1.9	8.3	17.5	−23.0	0.7	13.5	76	0	3	165	12.0	12.0
REGINA	−4.0	4.2	21.0	−33.5	28.8	35.6	221	10	7	**	9.3	9.3
SCOTT	−3.9	5.0	12.0	−23.5	13.5	17.4	92	0	4	161	0.8	0.8
SWIFT CURRENT	1.2	5.9	19.5	−25.0	22.9	35.0	227	2	10	137	15.4	15.4
MANITOBA												
BRANDON	−3.6	4.8	16.2	−26.0	8.1	12.1	51	0	3	**	3.4	3.4
MORDEN	−3.4	5.6	11.0	−22.0	13.4	15.0	63	7	***	2	*.*	*.*
GLENLEA	−1.5	5.2	6.0	−28.0	7.6	8.6	30	2	3	155	0.0	0.0
ONTARIO												
DELHI	−1.7	−1.4	18.5	−18.5	41.1	71.3	84	0	8	**	8.4	11.4
ELORA	−3.7	−1.0	15.9	−23.8	24.5	28.7	39	0	3	**	*.*	9.8
GUELPH	−3.3	−1.4	17.5	−25.6	39.8	44.0	70	0	7	114	7.7	9.6
HARROW	−0.2	−1.4	16.0	−14.0	22.6	81.6	109	0	8	73	10.8	14.3
KAPUSKASING	−8.5	1.1	12.0	−35.0	26.1	21.4	40	21	6	174	1.8	1.8
OTTAWA	−3.6	−0.7	15.5	−24.5	55.6	69.6	117	12	12	157	6.5	6.5
SMITHFIELD	−1.5	−0.1	16.7	−22.7	34.7	70.8	83	0	8	**	14.4	15.0
QUEBEC												
LA POCATIERE	−5.6	−1.2	12.0	−24.0	48.2	52.8	78	13	9	186	1.8	1.8
L'ASSOMPTION	−4.5	−0.8	14.0	−25.0	65.6	59.4	85	15	10	156	3.3	3.3
NORMANDIN	−10.4	−1.7	11.2	−34.7	*.*	25.8	43	6	6	203	0.0	0.0
NEW BRUNSWICK												
FREDERICTON	−3.1	−0.6	18.5	−24.0	50.3	62.0	77	0	6	178	8.3	10.3
NOVA SCOTIA												
KENTVILLE	−2.5	−1.5	17.0	−21.0	132.0	149.4	152	26	9	160	6.9	12.7
NAPPAN	−2.9	−0.6	13.0	−23.0	107.0	136.3	152	5	9	153	2.0	5.3
PRINCE EDWARD ISLAND												
CHARLOTTETWN	*.*	*.*	*.*	*.*	*.*	*.*	**	***	***	**	*.*	*.*
NEWFOUNDLAND												
ST.JOHN'S WEST	−2.6	−0.6	12.0	−14.0	58.2	155.9	104	2	14	127	3.3	3.3

Courtesy of Agriculture Canada

Courtesy of Agriculture Canada

...continued from page 5

Snowfall totals were above normal in all areas, with a number of locations in Nova Scotia recording more than double their normal for the month. Several locations reported the third highest snowfall total on record for the month of March. Halifax, reported a total of 98.6 cm, setting a new record for the month of March (records began in 1961). The previous record was 93.5 cm set in 1971.

During the first three weeks of the month it felt as though winter would never end, as a series of storms battered the Maritimes. Some locations had received over 100 cm of snow by the time the last storm had moved away. While the snow banks grew, snow removal budgets dwindled in many areas. Strong winds, freezing precipitation and rain also accompanied these storms. Schools and businesses were shut down and all forms of transportation were disrupted. Power was interrupted, as well, there were numerous cancellations and accidents.

The highlight of the month was a fierce storm that struck the Maritimes on the weekend of the 13th and 14th. After devastating the east coast of the United States, the storm moved into the region, bringing strong winds, snow and rain.

The snow began falling late on Saturday, the 13th, turned to freezing rain, ice pellets, and then to rain, with the largest amount of rain falling in Nova Scotia and the heaviest amounts of snow in parts of northern New Brunswick. The Halifax area of Nova Scotia received 36 mm of rain in 6 hours on top of 12 cm of snow. Winds were extremely strong, with many locations reporting gusts in excess of 100 km/h. Shearwater, N.S., reported a gust to 119 km/h, but the maximum occurred at Grand Etang, near Cheticamp, N.S., with a gust to 211 km/h. The storm caused power outages, property damage and transportation delays. In the Cheticamp area of Nova Scotia, the hurricane force winds left a path of torn roofs and damaged houses. The 15 patients at Sacred Heart Hospital had to be evacuated after high winds ripped a large section of roof from the building. In other areas, the wind caused flight delays and cancellations, and forced Marine Atlantic to cancel ferry crossings from various ports. Windows were broken, shingles torn from roofs and siding stripped from houses, as well as wide spread power outages and some localized flooding.

Conditions were not much better offshore, where hurricane-force winds churned up 15 to 20 meter waves. The 177 meter ship Gold Bond Conveyor sank in heavy seas, with all 33 of its crew lost early on the 15th, about 110 nautical miles south of Cape Sable Island, N.S.

Extremely cold air spread into the Maritimes late on the 17th, causing temperatures to drop dramatically. Some parts of northern New Brunswick experienced a temperature drop of 25°C in 18 hours. In Nova Scotia, the temperature dropped from overnight values of around 6°C to -10°C early on the 18th. New daily record low minimums were set on the 18th and 19th.

It has also been a bad year for ice, with many harbours in Nova Scotia jammed by ice packs. Pack ice that drifted into the Halifax Harbour on the 17th, tied up the Halifax-Dartmouth ferry service and sent hundreds of commuters looking for alternative transportation. The ferries have not been tied up since the big ice-up in 1986, when the service was shut down for eight days.

Sunshine was above normal in most areas, with northern New Brunswick receiving the most. The exception was at Yarmouth, N.S., where the total was 11 hours below normal.

The first real sign that winter might be coming to an end arrived on the 26th, when very mild air moved into the region. Maximum temperatures climbed to record-breaking values on the 26th, 27th and 28th. Saint John, N.B., reported a maximum temperature of 16.7°C on the 27th, tying their record high maximum for the month of March set on the 30th in 1945. Records at Saint John date back to 1871.

Newfoundland and Labrador

A changeable weather pattern prevailed across the Island, with below-normal temperatures and higher than normal snowfalls. The first three weeks were the coldest, but during the final week of the month, the temperature in some areas, climbed to the double digits. Overall, the temperature averaged almost 3°C below normal, and the Labrador ice pack has drifted further south than usual for this time of the year.

Deer Lake recorded the lowest temperature, -29.0°C, while at the other extreme, St. Lawrence in the south, reported a maximum of 12.4°C. Precipitation was above normal, with most of it falling during the first three weeks of the month. Gander, on March 18, received 58.6 cm of snow, a new record. Surprisingly, hours of bright sunshine over most of the Island were higher than normal.

Westerly winds prevailed throughout the month. At the infamous Wreckhouse, winds were recorded at 177 km/h on the 14th.

A colder month of March, with more sunshine and less precipitation was the overall picture for Labrador. The temperature averaged nearly 4°C colder than normal; accordingly, there is a vast area of sea ice off the coast of Labrador. On March 5, Goose Bay set a new minimum temperature record of -33.0°C. Almost all areas reported less precipitation than normal, with the average departure being approximately 30 cm. The exception was Goose Bay, which had 43.7 cm more snow than usual.

Sunshine was above normal across most of Labrador, with Churchill Falls reporting 65.6 hours more sunshine than usual.