Chinook

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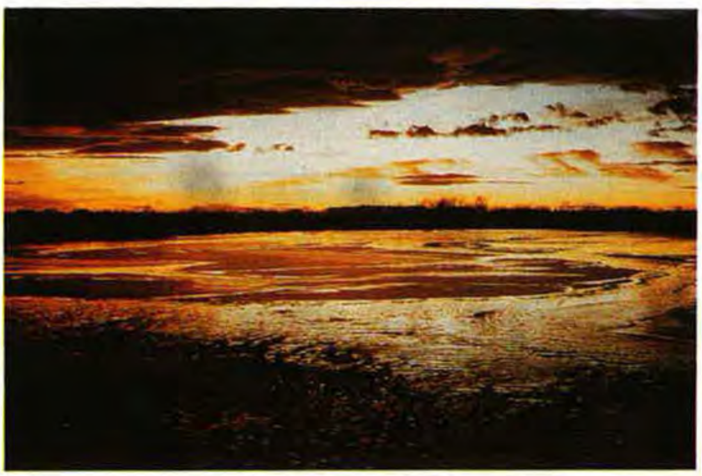
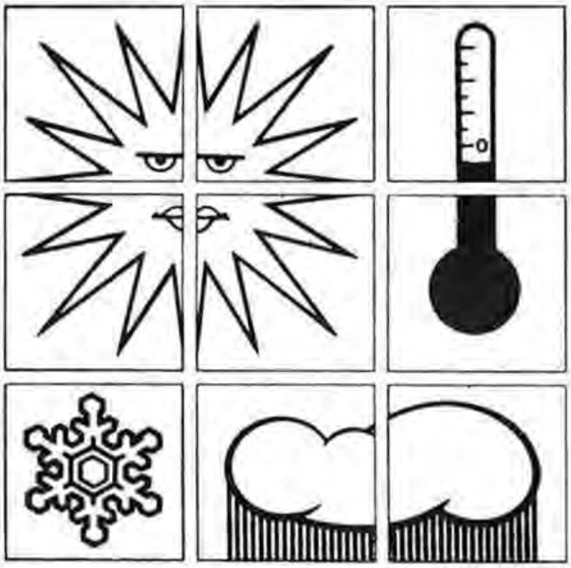
VOL. 9 NO. 3 SUMMER/ÉTÉ 1987





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FROM THE EDITOR'S DESK

The two articles by Barry Grace in this issue – the Alberta chinook and the related phenomenon of soil erosion – are, in a sense, a reminder that the name of our publication is connected with that infamous weather phenomenon. In this issue we are revisiting the chinook and some of its important impacts. *Chinook*'s first issue in the fall of 1978 provided a satellite view of the cloud arch accompanying this warm, dry and gusty wind.

Since the magazine has been in existence now for almost ten years, we felt it proper to provide the readers with an up-to-date and rather extensive bibliography of articles and books published on this most Canadian of weather phenomena.

In this issue we also want to welcome to our readership a large number of weather observers. Through the kind generosity of the Atmospheric Environment Service, *Chinook* will be distributed to a select number of these most valuable contributors to meteorology in Canada.

Weather observers play a vital role in piecing together the complex weather and climate picture. They are a group who go back in history more than two centuries – well before Canada's Weather Service existed – and who can be found in many communities across the length and breadth of Canada.

We welcome your comments and look forward to your contributions. We will endeavour to publish your observations in *Chinook*, particularly if they pertain to peculiar, unusual or just interesting weather phenomena. Some of these are best described with pictures. We thus intend to start, with your cooperation, an Observer's Corner for the purpose of sharing your observations and insights with the meteorological and oceanographic communities in Canada.

This desk has thus far not been flooded with letters or contributions from our readers. So we will assume either they are in the mail or you are still working on them. The bottom line is that we need to hear from you, the good news, the bad news and your contributions.

We also continue to need your assistance in spreading the word and in getting the magazine into secondary schools, flying and yacht clubs, radio and TV stations and all those groups who in one way or another have an interest in weather and the oceans.

Hans VanLeeuwen

Contributions, enquiries, comments and suggestions from readers are welcome. They should be addressed to:
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COVER

Striking views of the Chinook Arch near sunset, with melting snow shown in the lower right photograph. Courtesy: Evan Gushul, retired photographer, Agriculture Research Station, Lethbridge, Alberta.

COUVERTURE

Prises remarquables de l'arche du chinook, peu avant le coucher du soleil, ainsi qu'une image de la fonte des neiges, en bas, à droite. Gracieuseté de : Evan Gushul, photographe à la retraite, Station de recherches, Agriculture Canada, Lethbridge, Alberta.

CHINOOKS

by Barry Grace

Chinook Arch at Lethbridge. Courtesy: Evan Gushul, retired Photographer, Agriculture Canada, Lethbridge.

The climate of southern Alberta was often referred to in historical records. Early explorers and traders in the late 1700s noted the warm west winds and mild winter climate of the area, where the climate is dominated by chinook winds. Few regions in Canada are so profoundly influenced by the direct and indirect effects of a specific weather phenomenon.

Chinook is the name applied to strong, warm, dry winds that sweep down the eastern slopes of the Rocky Mountains. Early North American legends claim that the winds originated in the homeland of the Chinook Indians, who dwelt in the Columbia River area of Washington State. In other countries such as Austria, New Zealand and Japan, the winds that develop along the lee sides of mountain ranges are referred to as foehn winds.

Chinook winds in North America influence the climate of Alberta, Saskatchewan, Montana and North Dakota. In most of these, an occasional warming is the only effect of a passing chinook. In southern Alberta, however, the chinook winds are a dominating climatic factor. Here, the frequency is greatest, with the Lethbridge vicinity receiving the most chinooks.

The chinook is a meteorologically complex phenomenon. Simply stated, the chinook is a warm, dry wind descending the leeward side of the mountains. Daily temperature changes of 20°C or more are possible during winter chinooks, and wind speeds of 60 to 100 km/h are common. Figure 1 displays temperature and wind speed data for the chinook conditions of late December 1984 and early January 1985. It can be seen that the maximum and minimum temperatures for January 1 differ by more than 25°C.

A chinook is the result of the passage of a typical mid-latitude low-pressure centre into which air is drawn at the lee of the Rocky Mountains. Often this is associated with a ridge of high pressure over the mountains (Figure 2). Since the mountains lie in the path of and at right angles to the main westerly air stream, disturbances are set up in this stream in the form of a wave train with troughs and crests roughly parallel to the mountain ranges (Figure 3). These are very similar to those in a small water stream. After water flows over a few small pebbles on the bed of the stream, little waves appear in the water just downstream from the pebbles.

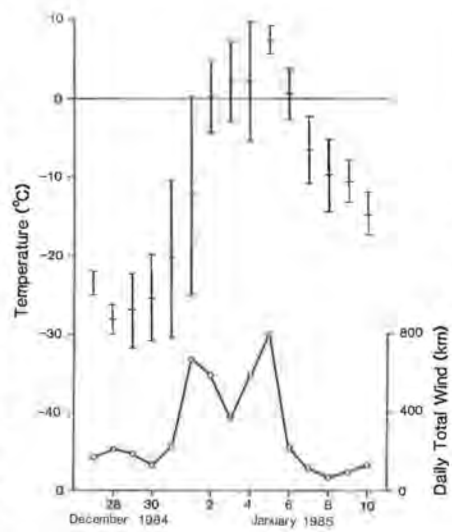

Figure 1 Daily maximum, minimum and mean temperatures and daily total wind run for late December 1984 and early January 1985.

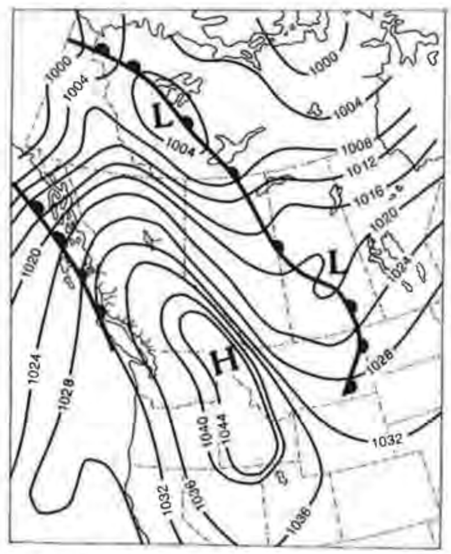

Figure 2 Surface analysis, 0600 GMT, for January 2, 1985 indicating a high pressure over the Rocky Mountains and a low pressure over southern Saskatchewan. Chinook conditions result from such weather patterns.

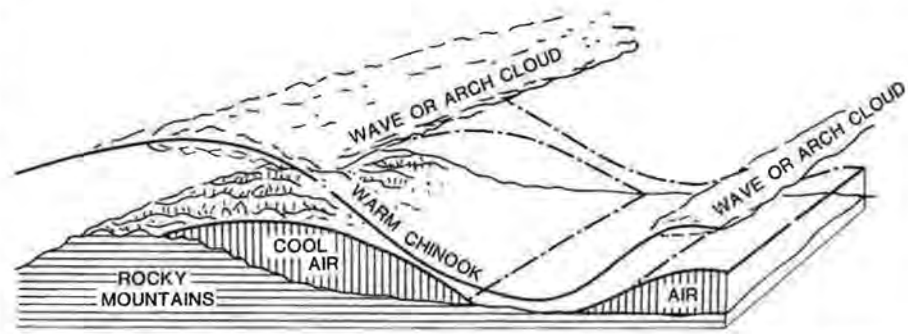

Figure 3 Diagram of chinook waves that displace cool air over the Rocky Mountain foothills and the Prairies, with the Chinook Arch at the crest of the waves (adapted from Brinkmann and Ashwell, 1968).

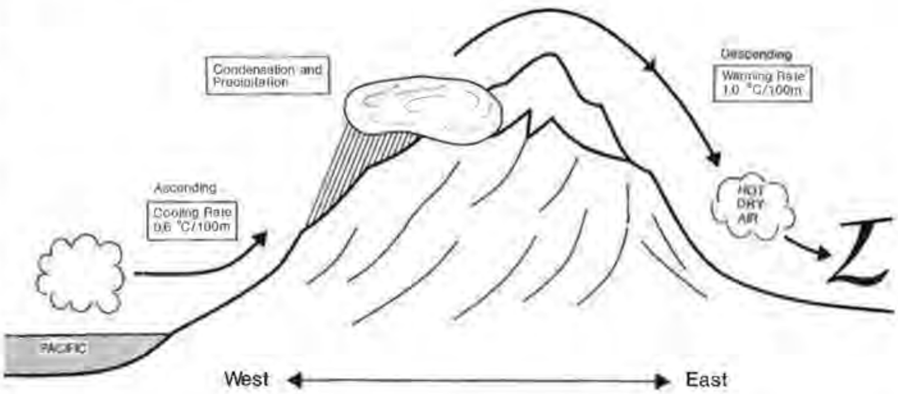

Figure 4 Ascending warm, moist Pacific air cools, crosses the Rocky Mountains, and warms as it descends to produce the hot, dry air of the chinook.

The size and amplitude of the chinook wave system depend mainly on the strength of the upper westerly winds and other factors, such as the air mass conditions and the local topography. This system is similar to our stream's, where the size of the waves depends on the speed of the stream flow and on the size and shape of the pebbles on the streambed.

With very light winds the amplitude of the chinook wave may not be sufficient for the trough to reach the ground. In this event the warm chinook air may lie a thousand metres above the ground surface. On each crest of the chinook wave train, a cloud formation known as the Chinook Arch may form within a linear band of lenticular altocumulus cloud. The Chinook Arch forms parallel to the mountains and stretches for tens to hundreds of kilometres in a roughly north-south direction (see Figure 3).

Chinooks are strongest in the foothills, where some areas are more prone to chinooks than others. Chinooks easily channel through mountain passes. Places near the Yellowhead Pass, Kicking Horse Pass, and Crowsnest Pass are prime chinook areas, with Crowsnest Pass in southern Alberta experiencing them the most frequently.

A strong chinook or foehn is often unpleasant. The combination of heat and excessive dryness together with strong, gusty winds may cause physiological as well as psychological reactions; irritability, headaches, etc., are common, especially in "weather sensitive" individuals. Although several theories have been proposed to explain this "Foehn illness" the cause is still unclear. Although few people enjoy the strong winds that accompany chinooks, most do welcome the spring-like conditions that provide a break from the cold winter weather.

The effects of chinook winds are most dramatic during the winter when the subzero weather may become mild and spring-like within a few hours. The snow cover may completely disappear if the chinook lasts for a few days. Although the average annual snowfall at Lethbridge is 141 cm, it is unusual to have snow accumulations of more than 25 cm. More common is no snow cover, owing to the frequent chinooks during winter. However, chinook or foehn episodes are not limited to winter, and may occur at any time of the year. Although they are less frequent during the summer they still have a strong effect on agriculture. The warm, dry winds add stress to crops by increasing their evaporation and evapotranspiration rates in areas that normally experience limited precipitation.

During the fall and spring months when most farm fields are bare, the strong winds may cause widespread soil erosion. Strong chinooks in the early spring may also result in the loss of a newly planted crop. The small seedlings can be abraded by the drifting soil particles. Soil may be blown away from the shallow roots causing the seedlings to dehydrate and die. Entire fields must then be reseeded.

The high temperatures and low relative humidities that accompany the chinook winds are due to the cooling and heating of rising and descending air. Air expands and cools as it is lifted upwards. Conversely, it contracts and warms as it descends. The rate of warming or cooling for dry (low humidity) air is 1°C for every 100-m change in elevation. However, if the air is moist (high humidity) the rate is less, approximately 0.6°C per 100 m. Air that is compressed as it flows down to lower elevations on the eastern side of the Rocky Mountains is usually dry and thus warms at the more rapid rate of 1°C for every 100 m of descent.

Chinooks are intensified considerably if precipitation occurs in the air that ascends the windward or Pacific side of the Rocky Mountains. When this Pacific air ascends the western side of the mountains, it is moist and therefore cools at the slower rate. The cooling results in condensation and, hence, moisture is deposited as rain at lower elevations and as snow at higher elevations. During condensation and freezing processes, heat (termed latent heat) is released to the air mass. Thus, the overall air mass remains fairly warm. The descending air on the eastern side of the mountains is now dry and, therefore, warms at the faster rate of approximately 1°C for every 100 m (see Figure 4).

In this manner, the lee side (Alberta) benefits from the liberation of latent heat on the windward side. The main reason for the warmth is the difference in the cooling and warming of wet and dry air as it first ascends and then descends the mountains. Figures 5 and 6 show the high frequencies of warm winter days and high wind speeds, which indicate the occurrence of chinooks in the Lethbridge area.

Photograph of RCAF Station, Claresholm, Alberta, taken during the 1950s, showing typical wave clouds associated with a chinook situation.

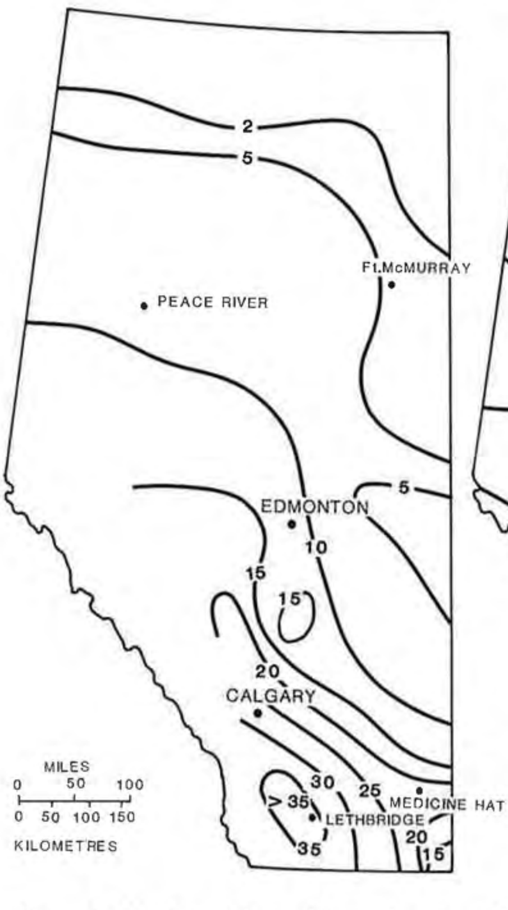

Figure 5 Number of days with maximum temperatures of 4.5°C or higher in January and February (adapted from Bentley).

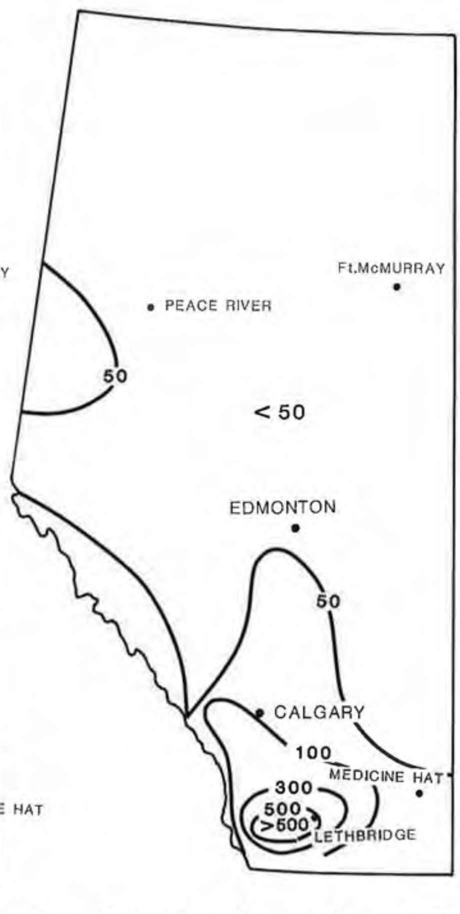

Figure 6 Number of hours each year with wind speeds equal to or exceeding 50 km/h (adapted from Bentley).

Dramatic melting of snow due to an Alberta chinook, from December 30, 1983 through January 3 to January 5, 1984. Courtesy: John Kolpac, Agriculture Canada Photographer, Lethbridge.

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Barry Grace is a Research Scientist specializing in Agricultural Meteorology at the Agriculture Canada Research Station in Lethbridge, Alberta.

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RÉSUMÉ *Les vents forts, chauds et secs qui balaient les pentes de l'est des Rocheuses portent le nom de Chinook. Ces vents influent sur les climats de l'Alberta, de la Saskatchewan, du Montana et du Dakota du Nord. C'est dans le sud de l'Alberta que les chinooks sont les plus fréquents. Lors des chinooks d'hiver, il est possible d'observer des variations de température de 20°C ou plus et, souvent, des vents d'une vitesse de 50 à 100 km/h (figure 1). En règle générale, les chinooks résultent de la circulation intense de l'air qui traverse la chaîne montagneuse. Ce phénomène est illustré à la figure 2. En observant les images de nuages, on peut voir qu'il existe une corrélation entre l'écoulement de l'air qui franchit les montagnes et une configuration type des ondes et des nuages. Le flux d'air descendant du côté sous le vent de la montagne produit de l'air sec et plus chaud accompagné de vents forts. Les chinooks exercent de fortes répercussions sur les températures et les taux d'humidité d'hiver et, en outre, ils causent souvent des réactions physiologiques et psychologiques. Les chinooks peuvent avoir des conséquences importantes sur la fonte des neiges et sur le contenu en eau du sol, y compris l'érosion. Les figures 4, 5 et 6 illustrent quelques effets du chinook en Alberta.*

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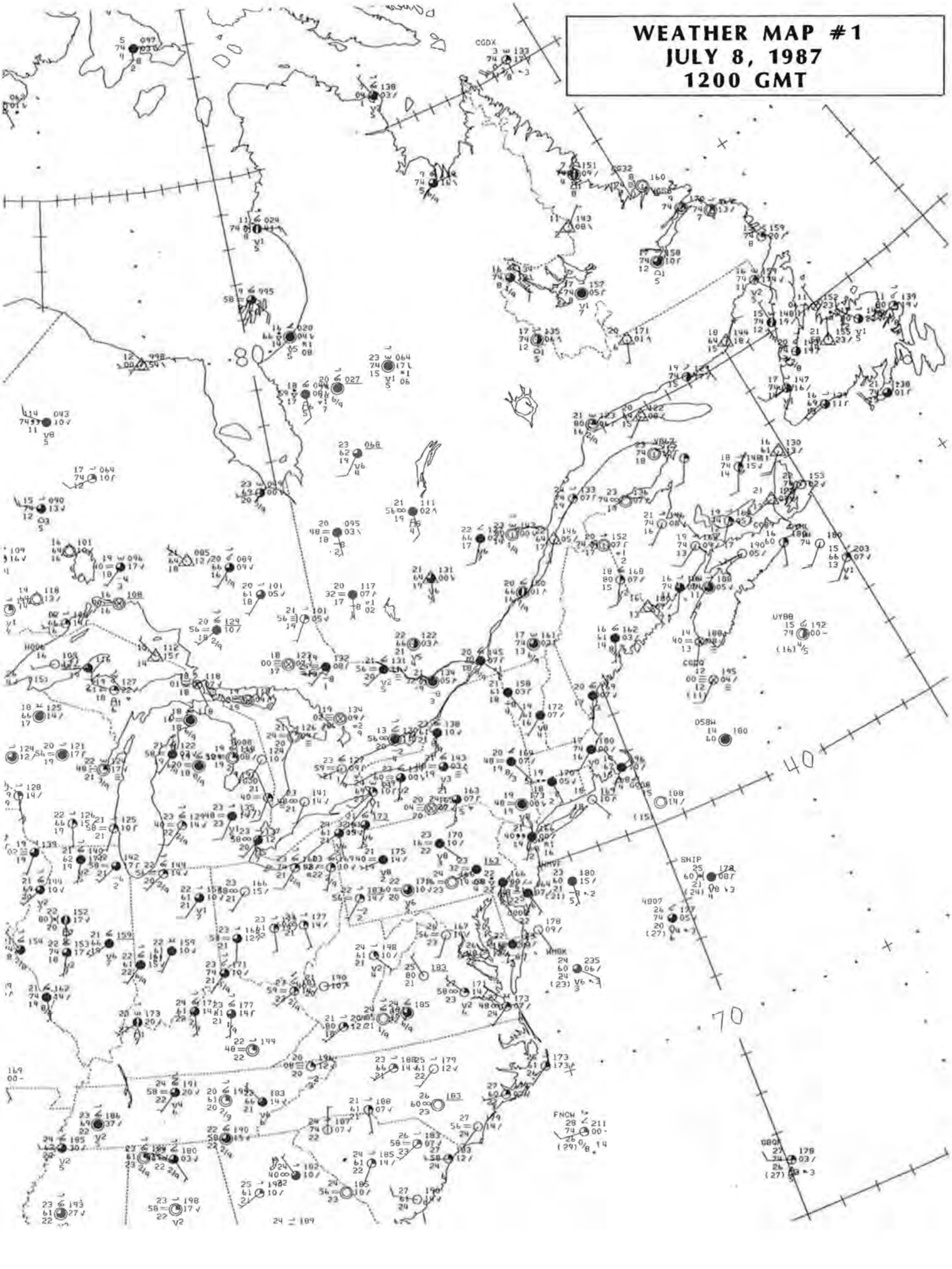
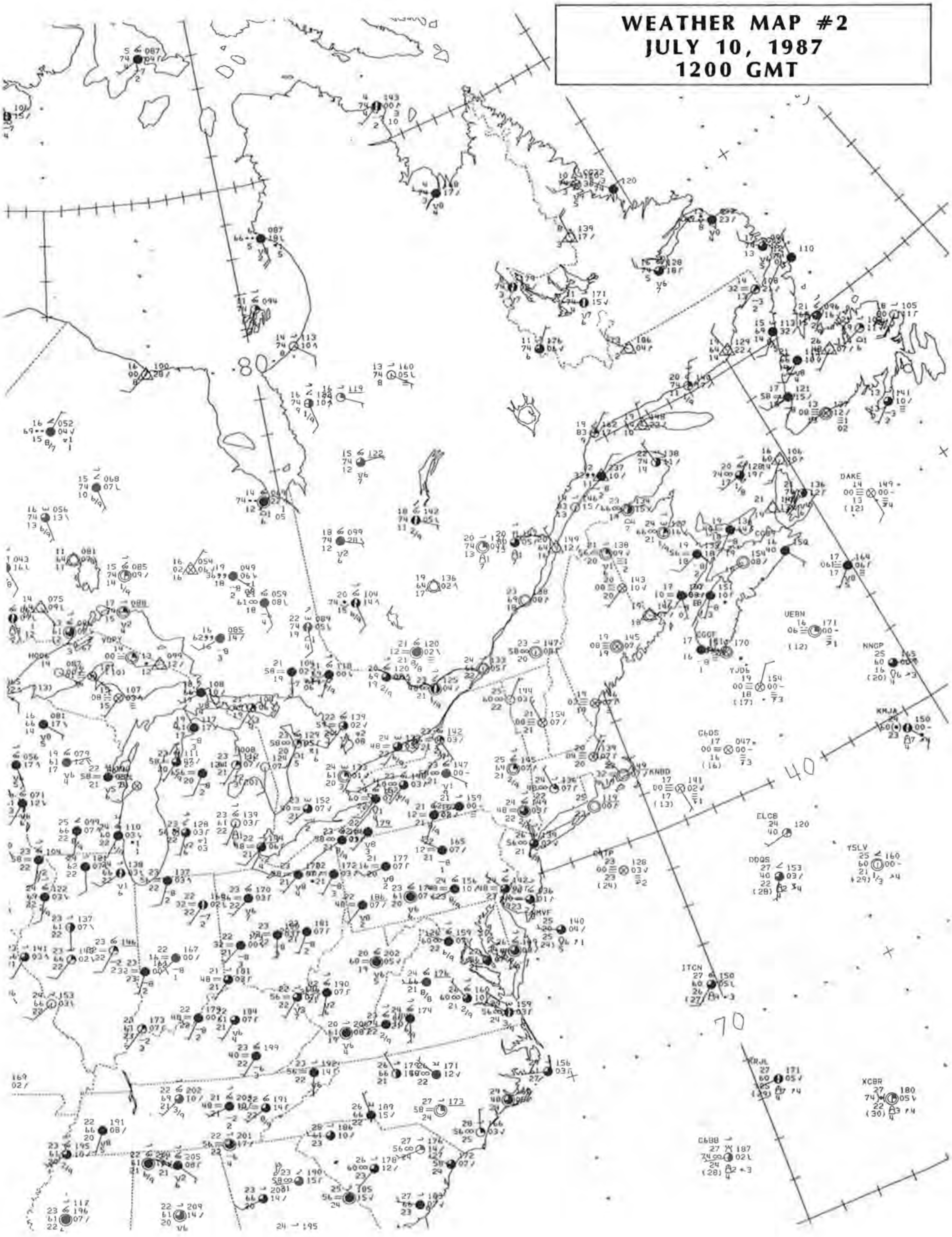
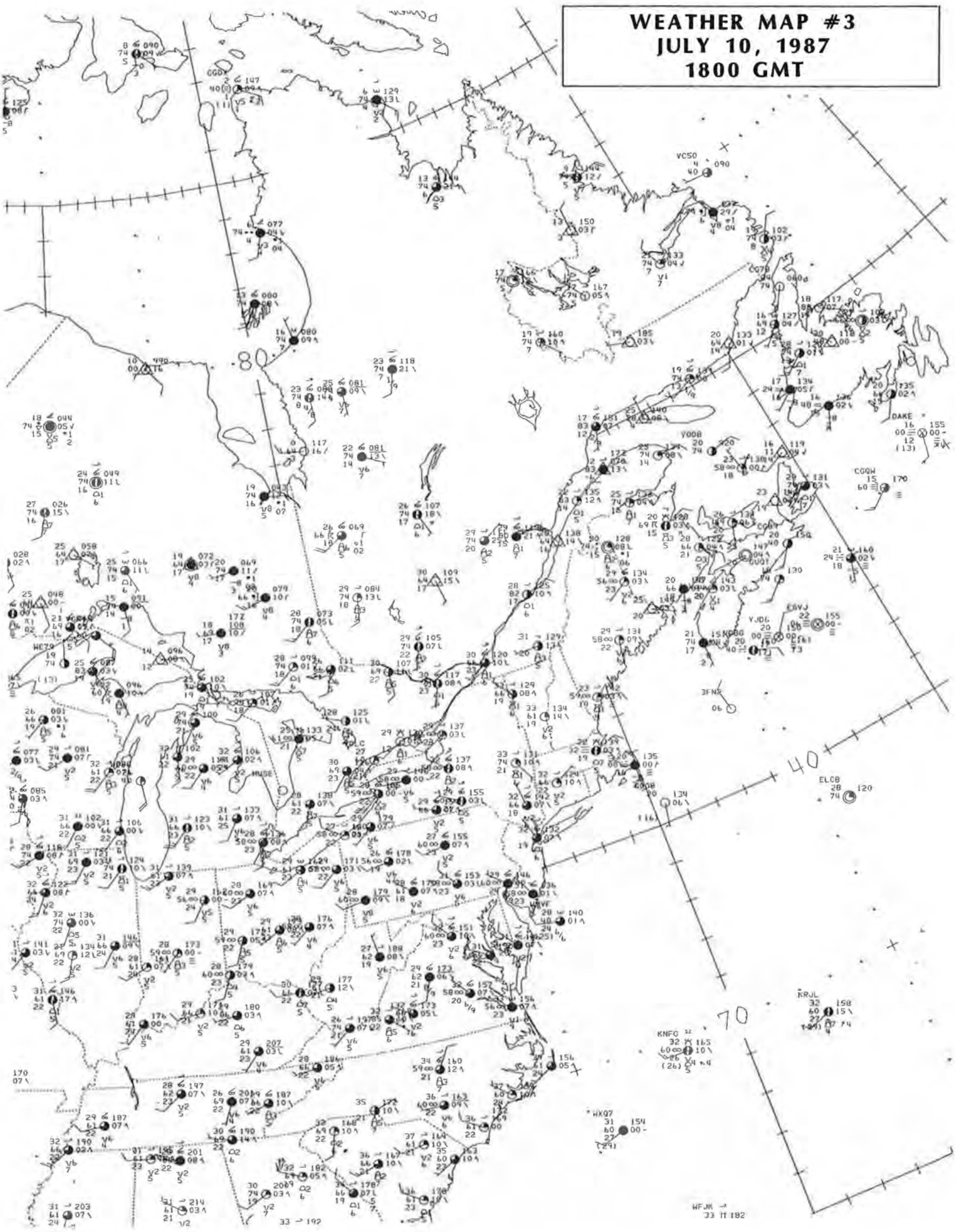
WEATHER MAP #1
JULY 8, 1987
1200 GMT



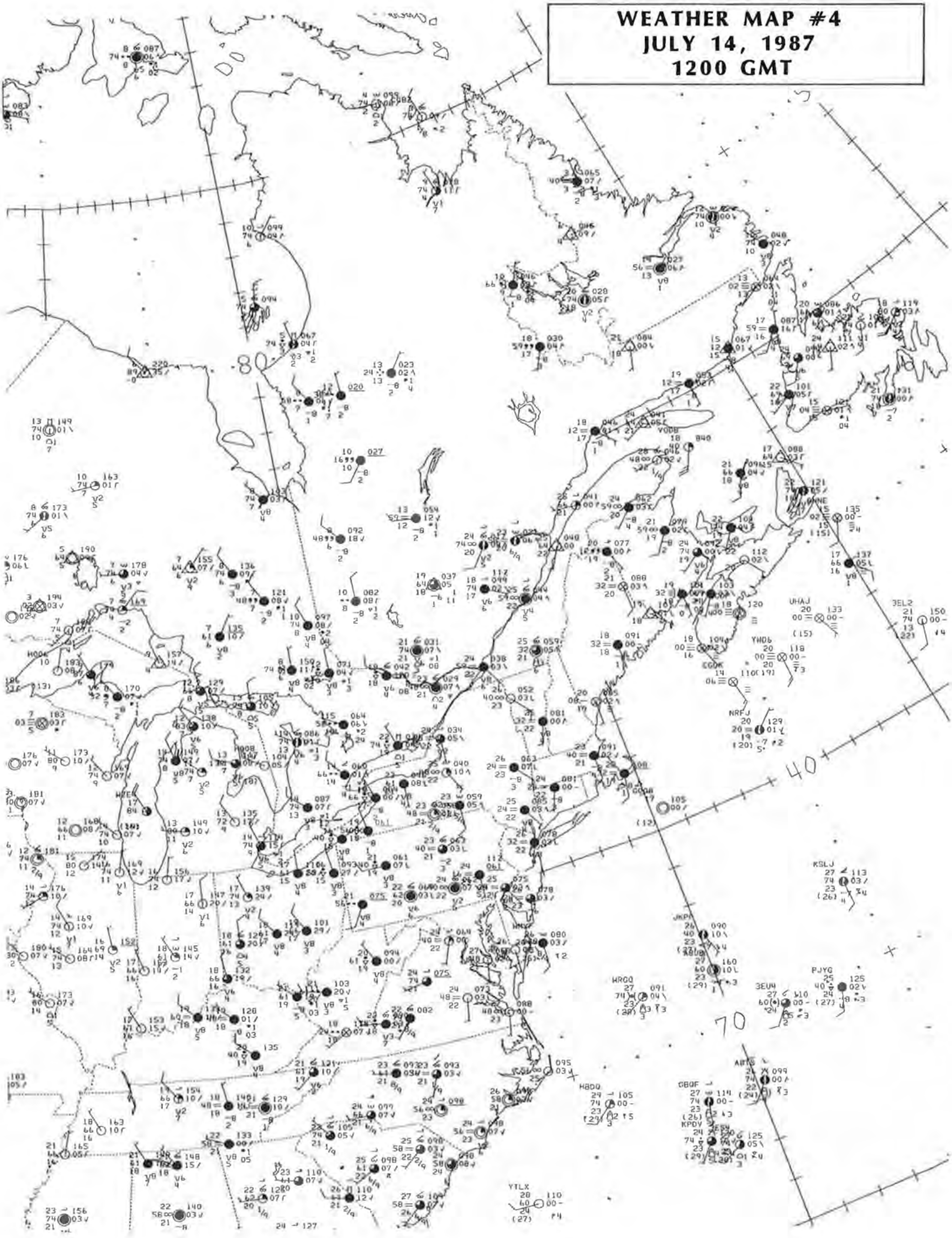
WEATHER MAP #2
JULY 10, 1987
1200 GMT



WEATHER MAP #3
JULY 10, 1987
1800 GMT



WEATHER MAP #4
JULY 14, 1987
1200 GMT



HOT AND COOL JULY BREEZES
Weather Map Series, July 8 to 14, 1987

by Hans VanLeeuwen

The month of July can typically be a scorcher on the eastern part of the continent. Early July 1987 was no exception – Plenty of hazy sunshine, afternoon thunderstorms, early morning fog, high afternoon temperatures and very high relative humidities!

The series commences with the 1200 GMT (0800 EDT) map (#1) of July 8. High temperatures and reduced visibilities in mist can be observed particularly around and south of the Great Lakes. The July 10 situation is shown for 1200 GMT and 1800 GMT (1400 EDT) on Maps #2 and #3, respectively. Nothing really significant had changed. The 1200 GMT situation on July 14 is entirely different. A low-pressure system is moving through eastern Ontario with a cold front extending south-southwestward through central Pennsylvania into eastern Tennessee. Cooler air behind the front is bringing much desired relief from rather uncomfortable and muggy weather.

The following activities are suggested:

1) Analyse the temperatures and dew points at intervals of 2°C.
2) Note the high *moisture content* of the air over the area; the higher the dew point, the higher the amount of water vapour in the air (measured in grams of water vapour per 1000 grams of dry air).
3) Notice the high *relative humidities*, as indicated by the temperatures being very similar to the dew points (for instance, on Map #1: the temperature of 23°C and dew point of 21°C at Toronto, Ontario).
4) An isobaric analysis with isobars drawn at 4-mb (or 0.4-kPa) intervals will indicate the southerly flow off the Gulf of Mexico during the whole period, and the cyclonic circulation around the low-pressure system and the northwesterly flow behind the cold front on July 14.

Many other interesting features can be observed, such as the highest temperatures recorded on the maps, the areas of showers and thunderstorms, the fog reported by ships over the cooler waters south of Nova Scotia and Newfoundland, and by stations along coastal areas.

In order to carry out a meaningful analysis of the weather data plotted on each map, the coded information must be understood. A previous issue of *Chinook* (Volume 8, Number 2) contains a detailed explanation of the synoptic map plot and also a list of publications recommended for reading. If a copy of the above issue is not available one can be obtained by mailing a stamped, self-addressed envelope to the CMOS office in Ottawa, Attention: Editor, *Chinook* (Weather Map series; Vol. 9 No. 3).

ANSWERS TO ICEBERG QUESTIONS (*Chinook* Vol. 9 No. 1)

1. The estimated volume of the world's glacial ice is 2.7×10^7 km^3 or 2.7×10^{16} m^3. The surface area covered by the world's oceans is 3.6×10^8 km^2 or 3.6×10^{14} m^2. If we were to cover each of these square metres of ocean surface with a cubic metre of melted ice, the resulting layer would consume 3.6×10^{14} m^3 of our total ice volume. Since our total ice volume is 2.7×10^{16} m^3, it follows that we could create 75 such layers. Since each layer has a thickness of 1 m, ocean levels would rise 75 m if all glacial ice were to melt.

   Our calculated value of 75 m exceeds the predicted value. It ignores the volume reduction that accompanies any conversion of ice into water. It also ignores the fact that if ocean water volume were to increase, ocean sizes would increase as well. The amount of such an increase would be significant since a substantial quantity of the world's land surfaces are at present just above sea-level.

   It should be obvious that the intial volume of water in ocean basins is an unnecessary fact in this question.

2. Sea ice develops as the high latitude ocean surfaces freeze. Icebergs develop as high latitude land glaciers deliver and deposit massive ice fragments into adjacent seas. The area of polar seas covered by sea ice is extensive and shows considerable seasonal fluctuation. The area covered by icebergs is, by contrast, miniscule. Both types of ice move in response to wind and current. To create sea ice takes as little as a single winter season. To create an iceberg takes centuries. Newly formed sea ice is saline. With time, its salinity decreases. Iceberg ice contains fresh water. On the oceanic landscape, sea ice appears as a white plain interrupted periodically by low ridges and open water. Icebergs, on the other hand, appear as prominent block or pinnacled mountains sometims locked within an ice floe, sometimes floating in open water.

3. The answer is contained in the article.

4. The answer is contained in the article.

5. • The volume of the water cube = $1.0 \times 10^6\ m^3$.
   • Since 1 m^3 of pure water has a mass of 1000 kg or 1 tonne, 1.0×10^6 m^3 has a mass of *1.0×10^6 tonnes*.
   • Since the cube of ice has a density of 0.9, and since
   $$\text{Volume} = \frac{\text{Mass}}{\text{Density}},$$
   the volume occupied by this ice = $1.1 \times 10^6\ m^3$.
   • While the conversion of water to ice changes the volume of the ice, it does nothing to its mass. It is still *1.0×10^6 tonnes*.

Continued on page 64

WIND EROSION OF SOILS ON THE CANADIAN PRAIRIES

by Barry Grace

Wind erosion of soil has been a major problem throughout the history of agriculture on the Canadian Prairies. For ages, prairie soils were protected from the wind by a tight grass sod. Soil erosion by wind occurred soon after the land was broken and converted into tilled fields. With the adoption of summer fallow tillage practices in the late 1800s prairie farmers soon saw the winds blowing their topsoil away. By 1914, drifting was extensive throughout the chinook belt in southern Alberta, where high winds are the rule in the fall, winter and spring. It was here that the frequent outbreaks of wind erosion led to the development and widespread use of strip farming about 1918, and blade plowing and trash-cover tillage in the mid-thirties (see The Early History of Climate and Agriculture on the Canadian Prairies to be published in a future issue of *Chinook.*)

Soil erosion by wind is caused by wind blowing across an unprotected soil surface that is dry, loose and finely granulated. The loss of soil by wind involves two processes: detachment and transportation. The force of the wind, or the transfer of momentum by the wind to a surface, results in some detachment of tiny soil grains (0.1 to 0.5 mm). When the wind is laden with small soil particles, however, its abrasive action is greatly increased. The impact of these small, rapidly moving particles of soil dislodges other particles from the soil surface.

Once detached, soil particles are transported in three main ways: saltation, soil creep and suspension. The first and most important, saltation, is the movement of soil by a series of short bounces along the ground surface. The particles remain close to the surface as they bounce, seldom rising more than 20 or 30 cm. Soil creep is the rolling and sliding of larger particles (0.5 to 1.0 mm) along the surface. The process of saltation enhances soil creep since the bouncing small particles strike the large ones on the surface and accelerate their movement along it. In the majority of soils, most drifting occurs by these first two processes. However, in fine-textured soils having a significant portion of particles smaller than 0.1 mm, the process of suspension may also be very important. These small dust particles, once dislodged, are lifted into the air and carried in suspension creating dust clouds. While some of these particles may only be carried upward in the atmosphere a few metres or tens of metres, others are carried to great heights and may be transported hundreds of kilometres. They return to the surface only when the wind subsides or when the rain washes them out of the atmosphere.

The actual velocity and turbulence of the wind near the ground depends on the nature and the heights of the surface irregularities. The intensity of the turbulence varies directly with the roughness of the ground surface and inversely with the height. The wind near the ground, in fact, is characterized by eddies of extremely variable velocity moving in all directions. This eddying, or turbulence, is what makes soil erode. Erosion of soil by non-turbulent air flow has never been recorded. Atmosphereic turbulence has a considerable tendency to increase the surface speed and hence the momentary frictional force of the wind against the ground.

Little can be done to reduce turbulence, but the surface speed can be reduced by various measures. Even a slight reduction in wind speed near the ground produces a relatively great reduction in the amount of soil erosion. The reduction of surface wind speed therefore should be one of the main principles for controlling wind erosion. For example, stubble mulching, created by permitting residues of crops to remain standing in the field so as to increase the surface roughness and extract momentum from the wind, reduces the wind speed at the surface and hence blowing soil.

One area especially prone to wind erosion is the chinook belt of southern Alberta. Here the weather associated with the high frequency of chinooks causes considerable loosening and structural disintegration of the soil surface. Alternating wetting/drying and freezing/thawing cycles tend to break down the soil aggregates into granules that are highly erodible by the wind. Climate directly influences

Strip farming introduced in the early 1900s in southern Alberta is one of the most effective methods of controlling soil drifting.

The processes of saltation and soil creep account for most soil drifting.

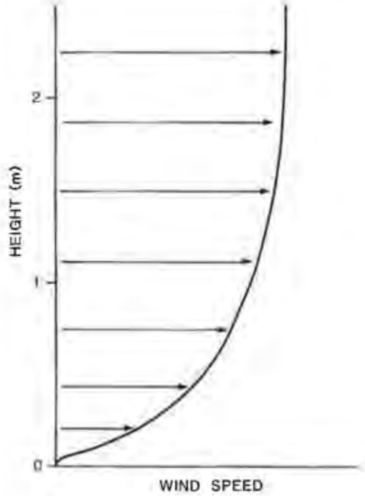


Figure 1 Profile of wind speed with height.

Soil drifting in southern Alberta.

wind erosion in two ways. The average wind speed for a region is a primary factor in determining soil loss as is the quantity and frequency of rainfall and the rate of drying of the soil surface. A moist soil is not eroded by the wind. Since temperature, precipitation and wind speed all affect soil moisture and wind erosion, a climatic wind erosion factor has been developed that incorporates both the average wind speed and soil moisture for a region. The local wind erosion factor that characterizes the erosive potential of the climate has been calculated as "high" for southern Alberta.

The rate of wind movement, especially gusts having speeds greater than average, will influence erosion. Tests have shown that wind speeds of about 20 to 45 km/h, depending on moisture content, are required to initiate soil movement for typical prairie soils. The quantity of soil carried by the wind increases rapidly at speeds above 20 km/h. It should be noted, however, that these tests were conducted in wind tunnels where the wind speed was measured at a height of only 15 cm. This does not mean that when we hear of wind speeds of 20 km/h we can expect to see soil drifting. Wind speed varies with height with winds speeds decreasing close to the surface (Figure 1). Reported wind speeds are usually recorded at a height of 10 m. To achieve a wind speed of 20 km/h at 15 cm, a wind of about 45 km/h at 10 m would be required. Wind speeds in excess of 45 km/h occur in the Lethbridge area a little more than 7 per cent of the time, with an annual average of 640 hours (see the accompanying table).

On flat, unprotected eroded fields, the rate of soil flow is zero on the windward or leading edge and increases with distance downwind until, if the field is long enough, the flow reaches a maximum that the wind of a particular speed can support. The intensity of erosion increases with duration of exposure owing to an increase in the amount of erodible fractions of soil produced by abrasion, or to the wearing away of non-erodible clods and surface crusts by the impact of particles through the process of saltation.

On a small isolated area, such as a narrow strip of fallow land at right angles to the wind direction, the intensity of erosion is rapid at first, diminishes with duration of exposure, and ceases as soon as the height and number of non-erodible soil fractions become sufficient to shelter the erodible fractions from the wind. The shorter the length of the erodible area, the less the amount of abrasion and hence the lower the rate of soil movement.

Over rolling terrain, where the slopes are relatively short, the wind speed is highest at the top of the knolls. Here the potential for soil removal from the crests is much greater. Small reverse eddies on the windward side of a knoll tend to move soil backward and downward, whereas lee eddies deposit soil on the lee side of the hill and form overhangs along the ridgeline (Figure 2).

Monthly frequency (%) of wind speed for Kenyon Field Airport, Lethbridge, Alberta (data courtesy of Environment Canada)

Month	Wind Speed (km/h)				
	Calm	1–20	21–45	46–75	>75
January	4.5	52.4	32.0	10.1	0.9
February	5.2	47.9	34.8	11.4	0.6
March	3.3	50.8	38.6	7.1	0.2
April	1.9	47.2	43.6	7.0	0.3
May	2.4	53.2	39.6	4.4	0.3
June	2.2	54.1	38.9	4.6	0.2
July	2.7	63.7	31.8	1.7	0.0
August	3.1	63.2	31.4	2.3	0.1
September	2.4	56.6	37.0	3.9	0.1
October	2.4	43.1	45.8	8.3	0.4
November	3.3	45.9	40.4	9.8	0.6
December	4.2	46.0	36.7	12.4	0.7
Mean	3.1	52.1	37.6	6.9	0.4

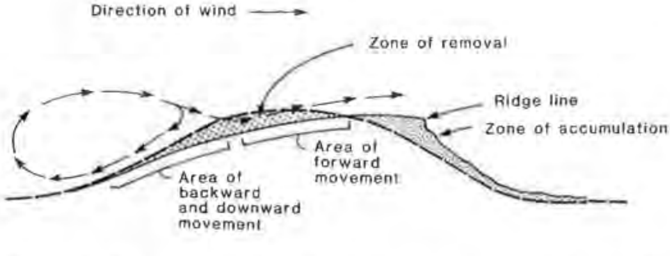


Figure 2 Cross-section of a ridge indicating zones of soil removal, accumulation and direction of movement when the wind blows at right angles to the ridge (adapted from Armbrust et al., 1964).

There appear to be irregular cycles of severe wind erosion that reflect cycles of the weather. Recurring periods of drought and high winds have worsened erosion. The general frequency of occurrence of periods of high wind and low precipitation can be predicted from past records, but the times when they will occur cannot be predicted. Constant preparedness for such periods is therefore essential if wind erosion is to be controlled.

SUGGESTED READING

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Photograph credits: Lethbridge Research Station Archives.

RÉSUMÉ *L'érosion éolienne des sols s'est avérée un problème majeur tout au long de l'histoire agricole des Prairies canadiennes. En général, l'érosion est causée par des vents qui soufflent à la surface d'un sol non protégé, composé de terre meuble, sèche, fine et granuleuse. Deux phénomènes entrent en jeu : le détachement et le transport. La force du vent et son action abrasive, produite par les petites particules de sol, contribuent fortement à la suppression de la couche supérieure du sol. Une fois détachées de la surface, les particules de sol se déplacent de trois façons principales : saltation (déplacement sous forme de petits bonds des particules à la surface du sol); reptation du sol (roulement et glissement des plus grosses particules à la surface du sol – 0,5 à 1 mm); et suspension (pour les particules mesurant moins de 0,1 mm). La diminution de la vitesse du vent à la surface est un des principes essentiels de réduction de l'érosion éolienne. Les degrés de vitesse du vent et de desséchement sont deux facteurs principaux d'érosion éolienne des sols. Parmi de nombreux éléments importants, on mentionne l'intensité des rafales, le profil vertical du vent, le profil du terrain (« caractère plat »), le type de sol, le contenu en eau, l'étendue et l'emplacement du terrain, ainsi que l'existence de végétation.*

Answers to Iceberg Questions

Continued from page 61

- The ice mass will stop sinking in the water when it has displaced a mass of water equal to its own mass, i.e. *1.0 × 10⁶ tonnes*.
- Since only 1.0×10^6 m^3 of ice is required to displace 1.0×10^6 tonnes of lake water, the amount of ice remaining above the water line is 1.0×10^5 m^3.
- Since the ice density = 0.9 and since its shape is cubic, it follows that its base will be at a depth of slightly over *90 m*.

6. Each plot on a cumulative curve is the sum of all previous plots added to the current value. Therefore, the last point plotted on this curve represents the total of all items plotted, i.e. the total annual crop of icebergs crossing latitude 48°N. The degree of slope expresses the rate of accumulation. A zero slope indicates zero accumulation. Our curve indicates the greatest accumulation of iceberg crossings occurs in May. To convert the cumulative curve into a graph that indicates monthly totals rather than accumulated totals, one simply subtracts from any point the value of the previous point. The resulting 12 numbers can then be represented on a bar or a line graph.

7. An object is physically stable if, when tipped, it attempts to return to its original position. When a stable object is tipped, its centre of gravity rises. The distance the centre of gravity rises as the object is tipped is an expression of the degree of stability possessed by that object. Tipping a basketball in water does not raise its centre of gravity. Consequently, in no position is it ever stable. Flat boards or rectangular posts, by contrast, are stable in a variety of positions. However, if thrown into water, they "choose" the positions that are the most stable. This is achieved when their broadest surfaces face upward.

   The stability of an iceberg is related to its shape. Tabular bergs, resembling fence boards, are very stable. Spherical (domed) bergs roll easily.

8. In 6° of latitude there are (6 × 60) or *360 nautical miles* of distance. From north to south through Greenland, one traverses (24 × 60) or 1440 nautical miles. At a speed of 200 nautical miles per hour, a plane would take *a little over 7 hours* to fly the distance.

9. Along the parallel 70°N, Greenland traverses approximately 33° of longitude. If these were latitudinal degrees, 33° would represent (33 × 60) or 1980 nautical miles. Since the distance between consecutive meridians decreases in accordance with the cosine of the latitude at which it is measured, the actual distance across the island at 70°N is 1980 × cos 70° or *677 nautical miles*.

10. Like 3 and 4, the answers to this question are contained in the article questions.

CLIMATE QUIZ

Match each capital city with its climate designated by the letter in the table below

City		Annual Mean Temperature (°C)	Annual Mean Precipitation (mm)	Days with Precipitation	Hours of Sunshine
Charlottetown, P.E.I.	a	10	647	138	2191
Edmonton, Alta.	b	3	466	124	2264
Fredericton, N.B.	c	2	384	111	2331
Halifax, N.S.	d	2	526	120	2321
Ottawa, Ont.	e	7	801	134	2045
Québec, Que.	f	4	1174	175	1852
Regina, Sask.	g	5	1109	156	1878
St. John's, Nfld.	h	5	1169	174	1818
Toronto, Ont.	i	8	1282	153	1885
Victoria, B.C.	j	5	1514	217	1497
Whitehorse, Y.T.	k	−1	261	120	1844
Winnipeg, Man.	l	−5	267	121	2277
Yellowknife, N.W.T.	m	7	875	137	2009

Answers will be supplied in the next issue of *Chinook.*

WINTER OF 1986–87 IN REVIEW

by Amir Shabbar

The season produced record mildness and a meagre snowfall over western Canada but held its icy grip over the East Coast.

Canadians from the Yukon to Ontario will remember the winter (December 1986–February 1987) for its record to near-record mildness and scanty snowfalls. In contrast, cold and stormy weather plagued Atlantic Canada and the northeastern Arctic throughout most of the winter. Southern Ontario and southern Quebec enjoyed record amounts of sunshine in February.

PFRA photo

Lack of snow cover allowed wind-driven soil erosion on many southwestern Prairie farms.

TEMPERATURE

A vast stretch of the Nation from the Yukon to the St. Lawrence Valley including Franklin District of the Northwest Territories enjoyed a warmer than normal winter.

The temperatures were 6 to 10°C above normal over the Prairies and the Yukon. The southwestern Yukon had the largest departures from normal, more than 10°C above normal. Balmy weather produced 3 consecutive months of record warmth. Winnipeg enjoyed its mildest winter ever (−9.4°C) and northwestern Ontario one of its warmest winters. At Edmonton, this winter ranked as the second warmest in 107 years (−4.1°C). Mild air extended into the Yukon and the District of Mackenzie producing the second mildest winter at Whitehorse (−7.0°C) and the mildest ever at Yellowknife (−18.2°). In contrast, Atlantic Canada and the northeastern Arctic experienced month after month of abnormal cold. The temperatures were nearly 5°C below normal over Baffin Island, where a prolonged cold spell extended into its ninth month by the end of February.

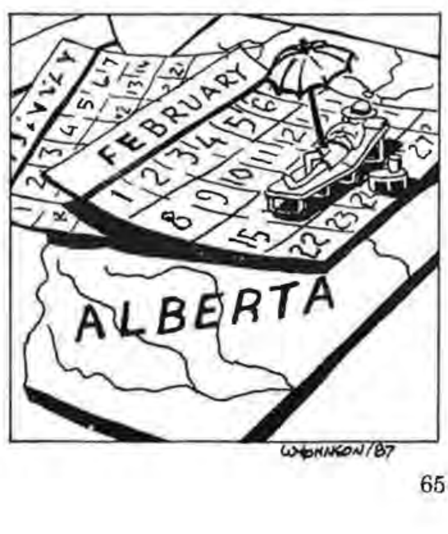
PRECIPITATION

Much of Canada had a drier than normal winter. Precipitation was less than half of normal over most of Alberta, southeastern British Columbia and parts of southern Quebec. During December, Grande Prairie had its least snowfall, 0.7 cm; at Calgary, the 37-cm seasonal accumulation was less than half the normal of 97 cm. Both the east and west coasts of Canada had more than their normal share of precipitation. Snowfall was particularly heavy over Newfoundland. Gander received a whopping seasonal total of 472 cm, nearly twice its normal of 270 cm. Over the Great Lakes and the St. Lawrence Valley, snowfall amounts were 50 to 90% of the long-term averages.

SIGNIFICANT CLIMATIC IMPACTS

Month after month of record mildness took the bitter sting out of the Prairie winter. Daytime temperatures soaring near the 17°C mark lured residents of southern Alberta to the beaches in the middle of February. The mild weather produced the warmest January in at least 8 Prairie locations. Most of the southwestern Prairies was free of snow during the winter. The lack of adequate snow cover permitted wind-driven soil erosion on many farms. On a positive note, cattle ranchers realized a substantial saving in animal feed costs since their cattle could graze on the snow-free range land.

Throughout interior British Columbia, a prolonged mild spell contributed to soft and muddy bush-logging roads. Logging operations suffered since the deteriorated roads could not support heavy machinery. The mild weather also hastened the blossoming of daffodils in British Columbia, and growers had to spray growth retardant on them to delay blooming until the traditional Easter period. Benignly mild weather together with below normal snowfall hampered fur trapping and adversely affected the sport of dog mushing in the



Chinook

THE CANADIAN MAGAZINE OF WEATHER AND OCEANS

WHAT? *Chinook* is a popular magazine concerned with two major components of the Canadian environment – the atmosphere and the oceans. It is published quarterly by the Canadian Meteorological and Oceanographic Society (CMOS).

Features in *Chinook* include articles, weather summaries, interpretations of satellite and other photographs, and news and notes. These appear in the language submitted (English or French). In addition, summaries of all articles appear in the other language.

WHY? The aims of *Chinook* are

- to increase public awareness of meteorology and oceanography in Canada and of their modern scientific and technological aspects and achievements
- to stimulate public interest in and understanding of the impact of climate, weather and oceans on Canadian society and economics
- to inform Canadians about the education, information and interpretative services available to them on climate, weather and oceans

WHO? Features in *Chinook* are chosen to appeal particularly to

- secondary school and community college students
- farmers, fishermen and foresters
- marine-recreation, sports and tourism operators and enthusiasts
- aviators
- amateur observers of natural phenomena
- specialists in other sciences
- environmentalists

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