Chinook

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

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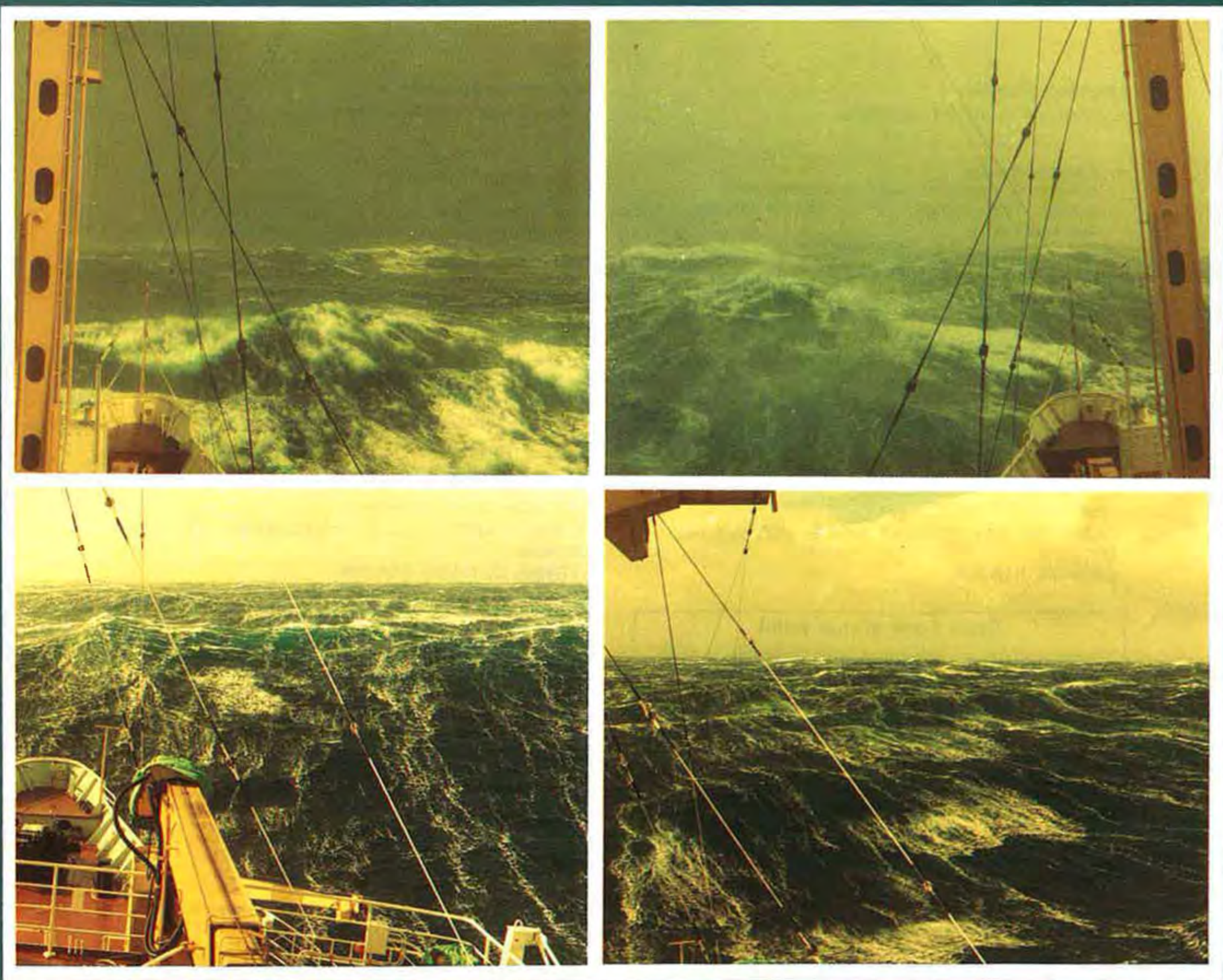

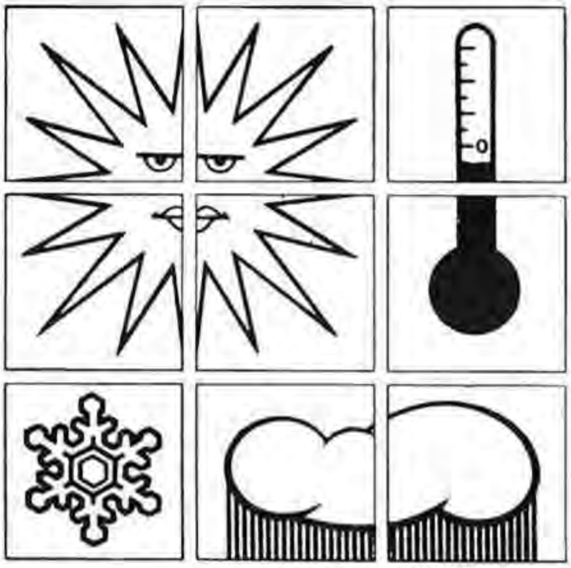

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LETTERS

Weather Observers Comment

Thank you very much for the copies of *Chinook*. I found the article on the Armada very interesting.

It could be interesting to have a forum for contacts with other weather observers across the country.

Maryanne West
Gibson's Landing, B.C.

Thank you for the recent subscription to *Chinook*. I have enjoyed reading the first two copies and look forward to more of them.

Mrs. J. Knight
Macdonald, Manitoba

COVER

Upper Left and Right Violent storm of October 24, 1977 at Ocean Weather Station Papa (50°N, 145°W) observed from the Canadian Ocean Weather Ship *Vancouver*. The conditions at the time (2340 GMT) were Force 11, winds from 230 degrees, at 56 knots with gusts to 68 knots. The probable wave heights were 11.5 to 16 metres (37 to 52 feet). The frequency of occurrence of Force 11 winds at Station Papa in the northeast Pacific is less than one per cent. The late October storm was a rapidly deepening storm that moved from an area to the southwest of Papa into the Gulf of Alaska where it occluded (Photo credit: R.F. Webber).

Lower Left and Right Force 9 or strong gale winds and sea conditions associated with a March 10, 1977 storm at the Papa location. Probable wave heights were 7 to 10 metres (23 to 33 feet) with the winds reported from 270 degrees at 45 to 55 knots. During a three-hour period the winds had increased from Force 8 (34 to 40 knots) to Force 9–10 (41 to 55 knots). The photographs were taken at 2250 GMT by J.H. Scarlett on board the Canadian Ocean Weather Ship *Quadra*.

Explosive deepening low-pressure systems over the oceans will result in gale- and storm-force winds, high waves and generally violent seas. See the detailed description in the article by Frederick Sanders on the "bomb", pages 77–81.

COUVERTURE

En haut, à gauche et à droite Violente tempête du 24 octobre 1977, à la station océanique Papa (50°N, 145°W) observée du navire météorologique océanique canadien *Vancouver*. À 2340 TMG, les vents sont de force 11, de 230 degrés à 56 noeuds avec rafales à 68 noeuds. Les vagues sont d'une hauteur d'environ 11,5 à 16 m (37 à 52 pi). Il y a moins d'une chance sur cent pour que des vents de force 11 ne surviennent à la station Papa, dans le nord-est du Pacifique. Cette tempête de fin d'octobre, à creusement rapide, provenait du sud-ouest de Papa et s'est occluse dans le golfe d'Alaska (Photo : R.F. Webber).

En bas, à gauche et à droite Vents de force 9, ou forts coups de vent, et conditions de la mer associées à la tempête du 10 mars 1977 à la station Papa. Les vagues sont d'une hauteur de 7 à 10 m (23 à 33 pi) et les vents de 270 degrés soufflent de 45 à 55 noeuds. Pendant une certaine période de trois heures les vents passent de la force 8 à la force 9–10 (de 34–40 noeuds à 41–55 noeuds). Photos prises à bord du navire météorologique océanique canadien *Quadra* à 2250 TMG par J.H. Scarlett.

Les systèmes de basse pression qui se creusent de façon explosive au-dessus des océans entraînent des coups des vents violents, des hautes vagues et des mers démontées. L'article de F. Sanders sur la "bombe" contient une description détaillée de ces images à la page 77.

Chinook

Fall / Automne 1987 Vol. 9 No. 4

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THE DARK DAY OF 1819

by Kevin Hamilton

There are many instances recorded in history of "dark days" when the sun has been obscured by atmospheric phenomena to the point where the daytime conditions are reported to be almost as dark as night. In those cases where the causes are known, the extreme darkness is generally attributable to dust from volcanoes or smoke from forest fires located upwind. Naturally the psychological impact of such darkness tends to be particularly impressive when the causes are unknown. The colonial period in North America is rich in memorable dark days of mysterious origin. This presumably reflects the presence of vast uninhabited forest regions where large fires could remain undetected.

From a Canadian perspective perhaps the most spectacular dark days were those that occurred in November 1819. While the darkness associated with this episode was observed over a large part of eastern North America, the effects were particularly striking in Montréal. In Montréal as well, the dark days were accompanied by other phenomena that combined to produce one of the most extraordinary natural events in Canadian history. Figure 1 is a picture of the city drawn about a decade after the events discussed in this paper (in 1819 the population was about 20,000).

The general sequence of events can be traced in contemporary newspaper accounts. The first unusual occurrences in Montréal were noted on Sunday, November 7, a day that dawned remarkably dark for the season. About 8 a.m. the sky appeared to be covered with a thick cloud, dingy orange in colour. A rain shower fell in the late morning and the rain was observed to be of an inky colour and impregnated with soot.

The happenings on November 7 turned out to be only a mild prelude to more spectacular and frightening phenomena on the ninth. The events in Montréal are nicely summarized in a story in the *Quebec Mercury* of November 16.

Figure 1 Drawing of the city of Montréal looking north from St. Helen's Island circa 1830.

Figure 2 Drawing of Notre Dame Street in the early nineteenth century showing the old Notre Dame church.

> Tuesday [i.e. the ninth] was a day that set anxiety on the rack and put conjecture at defiance. The morning opened with a clear serene sky and a gentle breeze from the northwest ... About 10 o'clock a.m. the wind became variable, veering around to the westward, and again became more northerly. A heavy damp vapour seemed to envelop the whole city and the appearance of the atmosphere indicated rain. As the forenoon advanced the sky became more and more surcharged with dense clouds, and the darkness increased to such a degree that by 12 and 1 o'clock it became necessary to light candles in all public offices in town, and even in the butchers' stalls in the market place they were found indespensibly necessary. The darkness still continued to increase, and with it, there appeared to be a general dread as to what might happen pervading every countenance ...
>
> A little before 3 o'clock there was a slight shock of an earthquake, distinctly felt in different parts of the city, accompa-

nied by a noise resembling the discharge of a distant piece of artillery ... about 20 minutes past 3 o'clock, after the darkness had gradually increased ... the whole city was instantaneously illuminated by one of the most vivid flashes of lightning ever witnessed in Montréal; this was suddenly followed by an awful peal of thunder, so loud as to shake the strongest buildings to their foundation ... The first peal was followed by a few others, and accompanied with a heavy shower of rain, similar to what had fallen on Sunday, but of a darker hue and apparently more charged with black sooty matter.

After the thunder and rain had subsided, the darkness did not entirely disappear as might have been expected, had it proceeded from a thunder cloud as usual. On the contrary, it still continued and seemed to increase until about 4 o'clock.

... As night approached men became less sensible of the continued darkness, they had become in some measure reconciled to its appearance, and were talking over its occurrence with comparatively more composure. But the events for the day were not yet closed. Between 4 and 5 o'clock it was discovered that lightning had struck the spire of the French church in Notre Dame Street [setting it on fire] ... About 8 o'clock the iron crucifix [on the spire] fell with a tremendous crash, and broke into several pieces ... Soon after it fell the fire was extinguished without destroying the spire or communicating with any of the adjacent buildings.

The church referred to was the old Notre Dame church (Figure 2), which stood close to the site of the present Notre Dame Cathedral whose construction began in 1824).

The impressive psychological impact of these strange phenomena is evident in the story quoted above. An even more vivid impression of the feelings of the populace is presented in a letter written in Montréal on the very evening of November 9. An extract of this letter was printed in the *Quebec Mercury* on November 12.

I have now sat down, although I feel very wretched in mind to give you an account of this awful day that has been a mystery to every one ... You may easily conceive the scene was truly awful ... God only knows where this darkness arose. It appears very alarming.

With the passage of time the journalists could take a more detached view of the events. However, the mysterious nature of the darkness was still impressive to at least some people, as illustrated by the following excerpt from the *Quebec Mercury* of November 23.

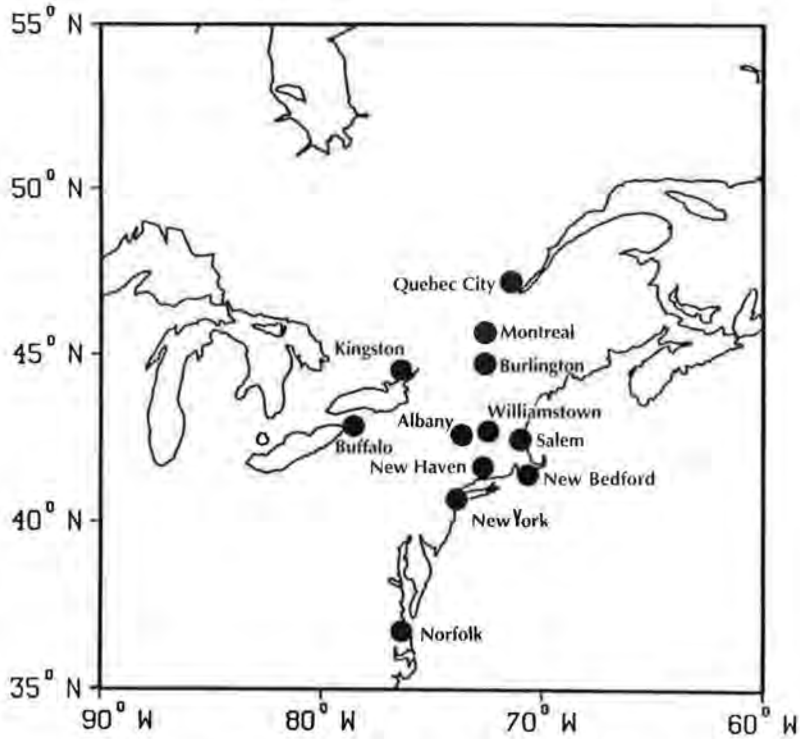

Figure 3 Map showing the localities mentioned in the text.

The late dark days, terrific thunder and lightning, it appears have not been confined to this province. Similar visitations were at the same time experienced in some parts of the United States. To account for such phenomena is, we fear, beyond the reach of man. Like meteoritic stones, they may serve as subjects for much conjecture and speculation ... Were we disposed to launch into the regions of hypothesis, how many fine theoretic threads we might spin out, forming a web of almost as much consistency as the spider's, though of far less use.

The reference to the widespread extent of the darkness is corroborated by both contemporary newspaper accounts and the records of amateur weather observers at a number of locations in eastern North America (see Figure 3 for localities mentioned in the text). A report in the *Kingston Chronicle* refers to smoky conditions on the afternoon of Saturday November 6, and then again in the evening of Monday the eighth and the morning of the ninth and throughout the day on the tenth. Darkness on the ninth was also reported by the newspapers at Quebec City (although it is noted that the darkness was less pronounced than at Montréal), Albany (New York), Burlington (Vermont) and Salem (Massachusetts). Smoky conditions ("so that no object at any considerable distance can be discerned") were reported as far away as Norfolk, Virginia, on November 8. Reports of dark and smoky conditions on November 10 are contained in weather diaries kept at New Bedford (Massachusetts), New Haven (Connecticut) and Williamstown (Massachusetts). The manuscript page for November 1819 in the record kept at Williams College in Williamstown is reproduced here as Figure 4. In this record, reference is made to smoky conditions each day from November 7 to 11, inclusive. The ninth is referred to as a "very dark day". In New York City the ninth was reported as "hazy" and the morning of the tenth as "foggy". In Buffalo, New York, rain discoloured by some "black substance" was reported on November 7.

What was the source of this extensive smoke pall? The obvious cause would be large forest fires burning somewhere to the west or north of the inhabited portion of the continent. There is at least one modern case of a smoke pall extending over much of North America. In September 1950 about 100 fires burning along the Alberta–British Columbia border produced a smoke cloud that affected most of Canada east of British Columbia and almost all of the United States east of the Mississippi. The main effects lasted for over a week. In some localities as far away as Buffalo, New York, the sky was so obscured that solar radiation intensi-

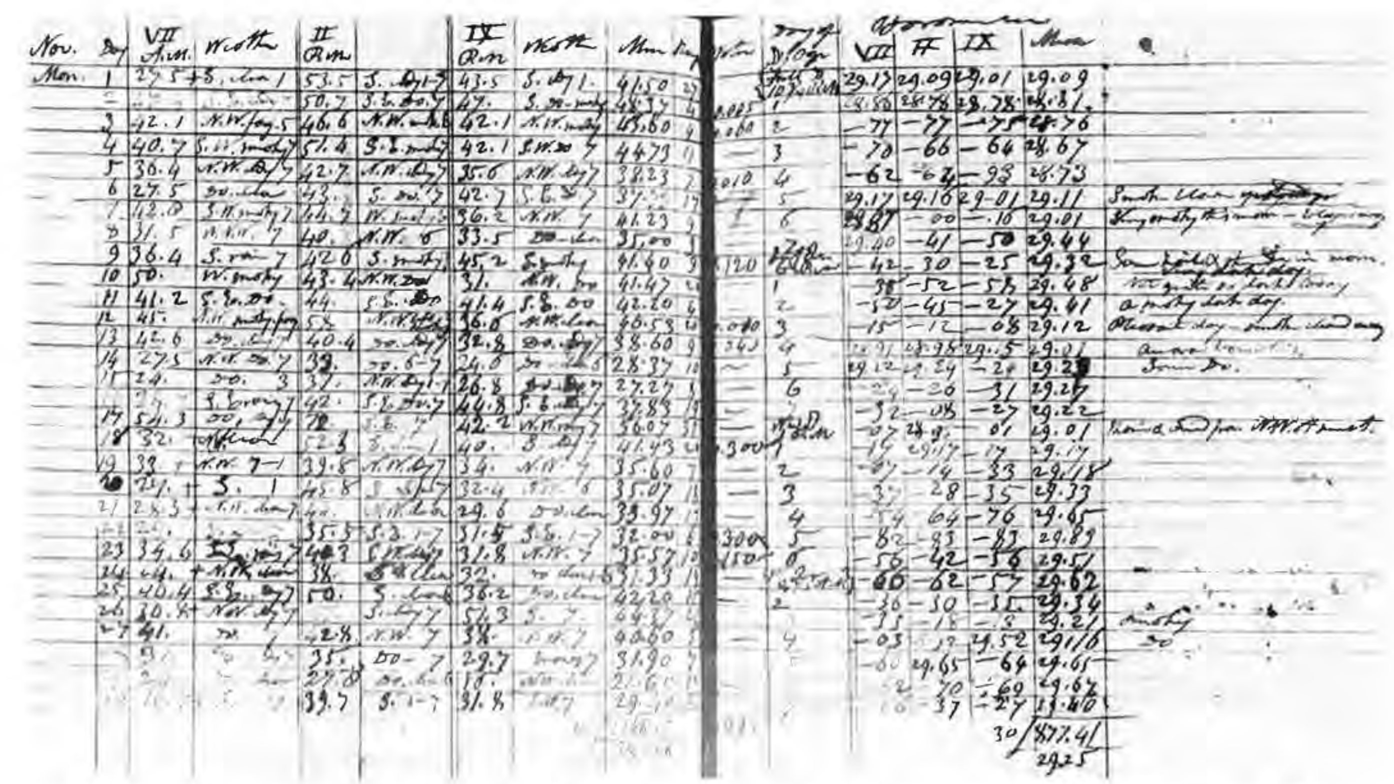

Figure 4 Manuscript page for November 1819 taken from the weather diary kept at Williams College in Williamstown, Mass.

ties at the ground during the afternoon were comparable to those normally observed during the pre-dawn and twilight periods. It is likely impossible to determine now the exact source of the smoke in 1819, but the example in 1950 cautions one to allow for the possibility that the forest fires responsible might have been located far upwind of the region where the pall was observed.

The smoke cloud in 1819 was rather remarkable for both its extent and thickness. However, what really made 1819 unique were the destructive thunderstorm and the earthquakes in Montréal that occurred simultaneously with the period of the most pronounced darkness on November 9. The occurrence of several small earthquakes at Montréal during the ninth is well attested. It appears that these were followed over the next few weeks by a number of other tremors in the surrounding region. In particular, one correspondent to the *Quebec Mercury* writing from Salmon River (about 100 km southeast of Kingston) reported over 40 perceptible earthquakes during the period between November 9 and 26. Some of these were "so heavy as to shake violently the houses, startle the inhabitants from their sleep, rattle stoves and even to raise surf in the river when the air was perfectly calm".

The simultaneous occurrence of the three menacing natural events – the darkness, thunderstorm and earthquakes – seemed to people at the time to indicate a connection among these phenomena, and must have added greatly to the anxiety of Montréal's citizens. Today, however, it would be difficult to argue on any rational scientific basis that there was any relation among the three events. Severe dark days have occurred in eastern North America every few decades, thunderstorms of sufficient violence to damage a tall church steeple are reasonably frequent occurrences (although these would be quite rare in November), and Montréal is in a region known to be prone to slight earthquakes. The simultaneous occurrence of the three events is a quite conceivable, although extremely unlikely, possibility. The actual observation of the the smoke pall, earthquakes and thunderstorm on the same day in 1819 must serve as a warning that coincidences that presumably would appear to be extraordinarily unlikely will in fact be observed on occasion.

SUGGESTED READING

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Kevin Hamilton is currently at the Geophysical Fluid Dynamics Laboratory of Princeton University. Previously he was on staff in the Department of Meteorology at McGill University and in the Department of Oceanography at The University of British Columbia. His research interests include stratospheric meteorology and climate variability. He also has a continuing interest in the history of meteorology and in the documentation of exceptional weather events in the past.

RÉSUMÉ *Au cours de novembre 1819 un voile de fumée couvre de grandes régions de l'est de l'Amérique du Nord. À Montréal, l'après-midi du 9 novembre est presqu'aussi noire que la nuit; en plus de cette noirceur extraordinaire, Montréal subit un léger tremblement de terre et un orage violent cause l'incendie du clocher de l'eglise Notre Dame.*

SPRING OF 1987 – A REVIEW

by Alain Caillet

The spring of 1987 will be remembered as exceptionally mild, even warm, a mari usque ad mare, *especially between the Rockies and northwestern Ontario. In the northern Arctic, on the other hand, spring was an extension of winter, which it seemed would never end. While temperatures were pleasant across the country, it was a season of sharp contrasts, and numerous records were set. In many places precipitation was deficient, but some people who thought summer had already arrived were surprised when snowstorms hit Alberta, Saskatchewan, Ontario and the Maritimes.*

The three spring months saw a continuation of the unusual circulation pattern that had maintained temperatures well above normal throughout most of the winter (with the exception of Baffin Island, the Atlantic Provinces and the coast of Labrador). Beginning in December, a moderate El Niño in the Pacific "froze" the upper-atmosphere flow in a configuration favourable to North America, and especially to Canada. Ridges of high pressure existed over the southern half of the country and long periods of sunny weather prevailed, allowing a southwesterly flow of warm air onto the continent.

All the provinces, as well as the Yukon, recorded above-normal spring temperatures. At Regina the average temperature for the three spring months was 4.8°C above normal. Table 1 gives the

Table 1 Regional mean temperatures (°C) over southern Saskatchewan (Estevan, Regina, Saskatoon) during spring (March, April and May) from 1955 to 1987. Anomaly = Mean – Normal (2.6°C).

	Mean	Anomaly		Mean	Anomaly
1955	1.10	−1.50	1972	3.36	0.76
1956	0.44	−2.16	1973	4.85	2.25
1957	3.01	0.41	1974	−0.16	−2.76
1958	4.15	1.55	1975	0.17	−2.43
1959	4.22	1.66	1976	3.52	0.92
1960	1.78	−0.82	1977	7.06	4.46
1961	3.52	0.92	1978	4.14	1.54
1962	1.91	−0.69	1979	−0.21	−2.81
1963	3.82	1.22	1980	5.17	2.58
1964	2.04	−0.56	1981	6.19	3.59
1965	−0.17	−2.77	1982	1.13	−1.47
1966	2.56	−0.04	1983	1.77	−0.83
1967	−0.12	−2.73	1984	4.09	1.49
1968	4.53	1.93	1985	5.83	3.23
1969	2.68	0.36	1986	5.83	3.23
1970	−0.06	−2.66	1987	6.97	4.37
1971	2.84	0.24			

"regional" mean temperature anomaly for three cities in southern Saskatchewan, and shows that spring 1987 was the second warmest in Saskatchewan for at least 32 years (just one tenth of a degree Celsius behind 1977).

By the end of May, all southern regions west of Quebec were in their sixth consecutive month of above-normal temperatures. The negative anomalies in the northern Arctic were less striking, but by the end of May there had been over twelve uninterrupted months of below-normal temperatures. With the exception of coastal and southern British Columbia, and northern Saskatchewan, the precipitation deficit that had marked the winter continued into spring, to the great consternation of farmers. From the beginning of May, there was an extremely high forest-fire risk in several of the wooded regions of the Prairies and northwestern Ontario.

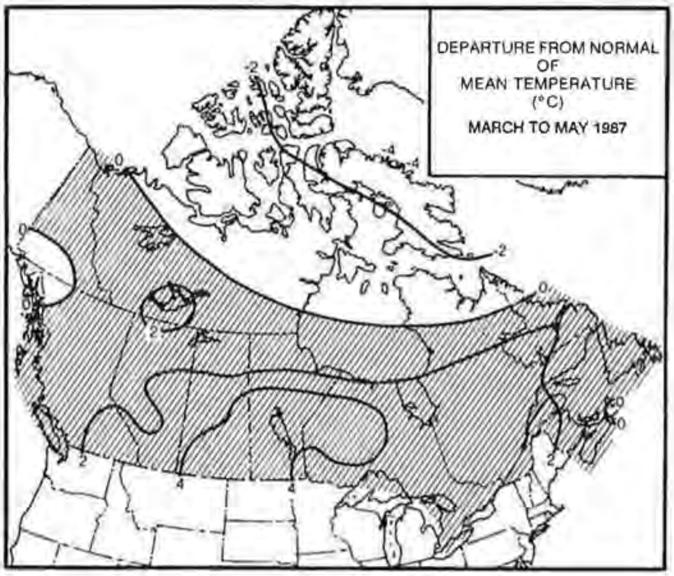
TEMPERATURES

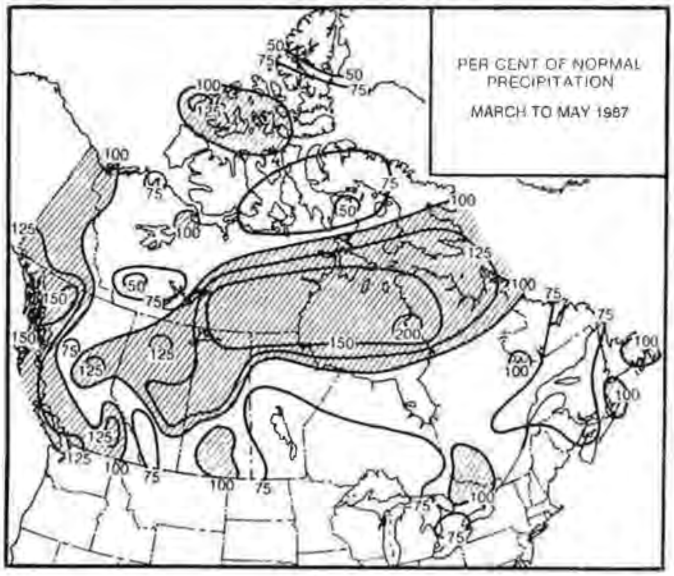
Spring is a transitional season, with one foot already in summer, but the other still in winter. This was perhaps more evident than ever this year, since the final blows of winter are harder to take when summer weather comes early. Numerous records were set and some startling contrasts in temperature occurred.

In March, despite record sunshine and a few daily maximum temperature records, the Yukon was still experiencing overnight lows of −50°C under clear skies, at a time when temperatures in the Arctic were finally getting back up to levels that had not occurred since November. At Abbotsford, British Columbia, the temperature reached 22°C on March 31, a record for the month. On the Prairies, early March temperatures ranged from 23°C at Medicine Hat in the south to −36°C at Fort Chipewyan in the north. The mercury almost hit the 20°C mark in southern Ontario, which had the mildest March since 1977, and nearly rose to 19°C in Quebec, even though the night-time minimums were near the lowest on record. Meanwhile the Atlantic Provinces still had a few weeks to wait: the effects of the equinox were not felt until Easter.

In April, however, record maximums were being set across the country: 33°C in Kamloops, B.C.; 31°C in Lethbridge, Alta.; over 30°C in northwestern Ontario and in Quebec; and 29°C in Charlo, N.B.

May saw the Yukon temperatures climbing above the 20°C mark, but record daily minimums continued to be set in the northeastern Arctic. In British Columbia, the weather returned to a more normal pattern, but the Prairies continued to have major contrasts: 34°C at Dauphin and Winnipeg; and −8.9°C at Edmonton during a snowstorm. In Quebec, and Newfoundland and Labrador, record daily maximums and minimums were being set regularly.





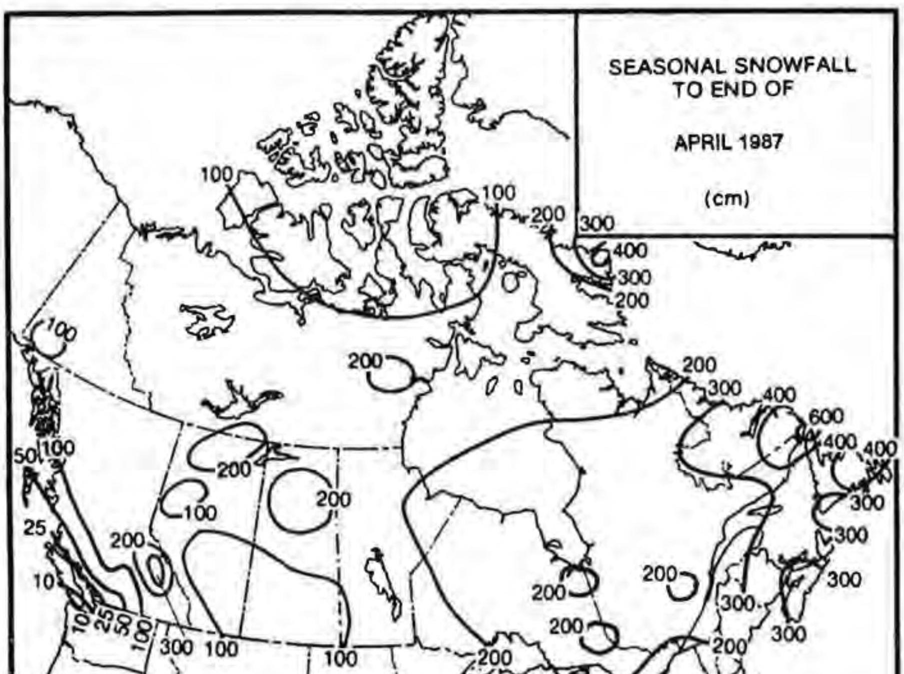
PRECIPITATION

Apart from the coastal regions of British Columbia, there continued to be a deficit of precipitation in the southern half of the country, just as there had been during the winter. Worried farmers were calmed temporarily by a few late storms: in southern Manitoba and Ontario in March; in central Saskatchewan and southern Alberta in April; and in central Alberta on May 19 (when Edmonton received its heaviest snowfall in 12 months). Several snowstorms hit the Atlantic Provinces, including one during mid-March in New Brunswick that disrupted all modes of transport.

IMPACT

The unusual spring weather naturally had both direct and indirect effects on economic activities and on the life of the country. On the plus side, the weather gave British Columbia farmers a two-week headstart and promoted spring seeding on the Prairies; the levels of the Great Lakes, which had been too high, dropped as a result of the dry weather and the increased evaporation accompanying the higher temperatures; and heating costs were reduced everywhere except in the Arctic Islands. On the minus side, it was rough going at times for those involved in forest-fire surveillance and control; the low moisture reserves in the soil were of concern to farmers, who feared a shortfall in grain production; and in the Arctic, the continuation of winter weather meant at least a 2–3 week delay in the shipping season.

Among the more direct effects of the weather, an avalanche caused by mild temperatures buried 7 skiers at Blue River, B.C.; the March snowstorm in New Brunswick left 8 people dead on the highways; April floods laden with ice carried away three spans of a railway bridge on the Sainte-Anne River in Quebec, and took out another railway bridge on the Saint John River in New Brunswick, and many riverside inhabitants had to be evacuated; and a severe storm in late May, accompanied by hail, caused several thousand dollars damage in Montréal.



Allain Caillet is a meteorologist with the Canadian Climate Centre and is a member of the editorial team of *Climatic Perspectives*.

ANSWERS TO CLIMATE QUIZ
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THE NORTH ATLANTIC "BOMB"

Storms That Are the Scourge of the Winter Ocean

by Frederick Sanders

How and why low-pressure areas form is of prime importance to voyaging sailors. Being able to recognize some important warning signals can help keep a vessel clear of dangerous storms. One particularly dangerous type of mid-latitude low-pressure system is the storm that develops explosively in the western North Atlantic and sweeps northeasterly across that ocean toward Iceland. Such storms, more prevalent in winter, are intense, powerful cousins to the milder spring/summer nor'easters and have been dubbed "bombs" for their strength and rapid intensification. A look at how they form can help us understand the less intense storms encountered in warm months when more sailors are active.

On 21 November 1980, a number of fishing vessels, among them *Fairwind* and *Sea Fever*, set forth from Hyannis, Massachusetts, for Georges Bank some 240 kilometres to the east. During the night the light southeasterlies of the afternoon backed to east and then north, building to storm force by dawn. Unable to do more than hold their own against the wind and huge seas, the vessels struggled for survival. Later in the morning, one of the *Sea Fever*'s crewmen was swept overboard to his death, and *Fairwind* broached and sank on encountering an 18-metre (60-foot) wave, leaving a single survivor of the crew of four. Subsequent litigation attracted considerable publicity, and the U.S. Government was initially found liable for failure to repair a damaged weather buoy southeast of Cape Cod, a decision that was subsequently reversed.

The accompanying charts (Figures 1, 3, 4, 6, 7, 9 and 10) show the explosive development of the northern of two low-pressure centres off the mid-Atlantic coast, which resulted in the vicious storm experienced by *Fairwind*, *Sea Fever* and the rest of the fishing fleet. The southern low-pressure centre (Figures 1 and 3) – which forecasters had been fooled into thinking would be the major storm – dissipated as the northern low intensified (Figures 3, 4 and 6).

Maximum winds of the northern low grew from 20 knots to 35 and then to 65 knots (hurricane force) in consecutive six-hour periods (Figures 6 and 7), as warm air from over the Gulf Stream interacted with much colder air to the north and west in a dizzying swirl. At the same time the central pressure dropped from 1012 to 990 millibars. An observation from the ship nearest the time and place of the *Fairwind* tragedy showed a north-northwest wind at 78 knots and 20-metre (65-foot) waves (Figure 9). Later, as this storm drifted east-southeastward and became more perfectly circular, it was named Hurricane *Karl* (Figures 9 and 10).

I first became aware of this type of storm while working for the then U.S. Weather Bureau in the International Aviation Forecasting Unit at La Guardia Field (New York) in the late 1940s. We referred to them in the vernacular as "bombs", a term that has somehow caught on. My students and I began systematic research on them some 30 years later, with a survey of their occurrence over the Northern Hemisphere and a study of the circumstances in which they arose.

As an arbitrary method of defining a storm as a bomb, we examined on the daily weather charts for the Northern Hemisphere each low in which the central pressure had dropped at least 24 millibars in 24 hours as the system travelled along. We called this test the critical deepening rate or, in other words, the amount the pressure dropped at the centre of the storm. This is important because as the central pressure drops the storm grows stronger.

In a three-year study for the period beginning in September 1976, we found that bombs are almost exclusively a maritime phenomenon and almost exclusively a feature of the colder season. On Figure 12, the major spawning grounds stand out: (1) the western Atlantic along and just north of the Gulf Stream from the Carolina coast to the Grand Banks with a weaker extension northeastward toward Iceland and the United Kingdom, and (2) the western Pacific along and just north of the Kuroshio Current from southern Japan across the Pacific nearly to the coast of North America.

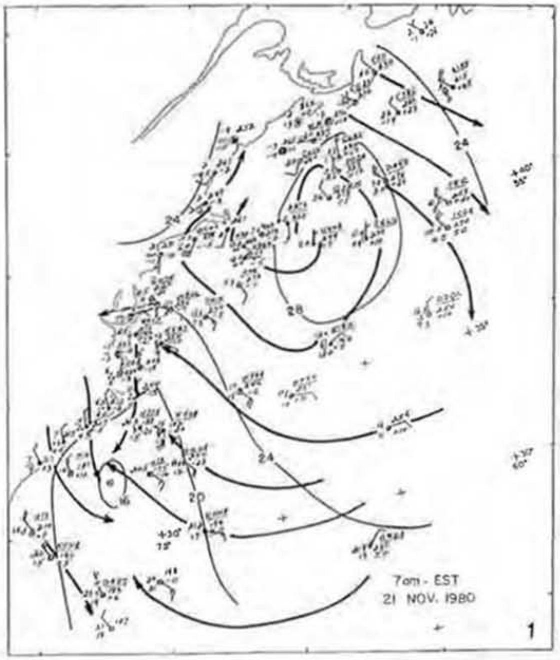
When we look at individual months, we see a gradual buildup from September to a peak of about two bombs every three days in the Northern Hemisphere during January. Then there is a rapid decline to very low (but not zero) values from May through August. (The deadly Fastnet storm over the eastern Atlantic and the Irish Sea in August 1979 was a bomb in a fairly unlikely spot and season.)

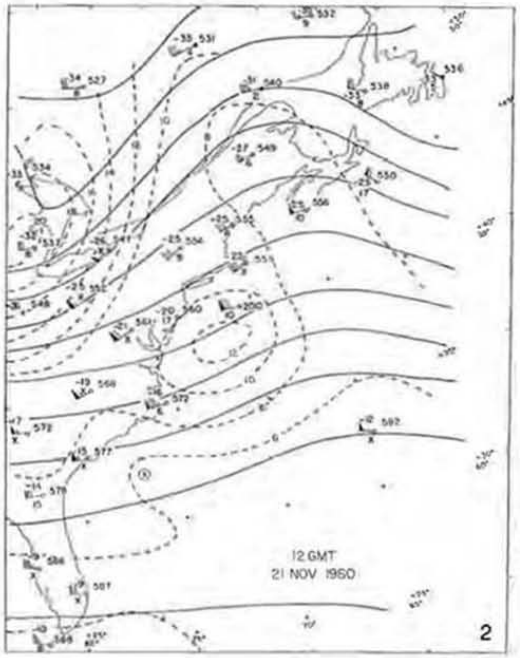
The total number of bombs is greater in the Pacific than in the Atlantic, but the larger number of extreme storms, exceeding twice the threshold deepening rate that classifies them as bombs, occur in the smaller oceanic basin, confirming the reputation of the North Atlantic in winter as the most dangerous ocean.

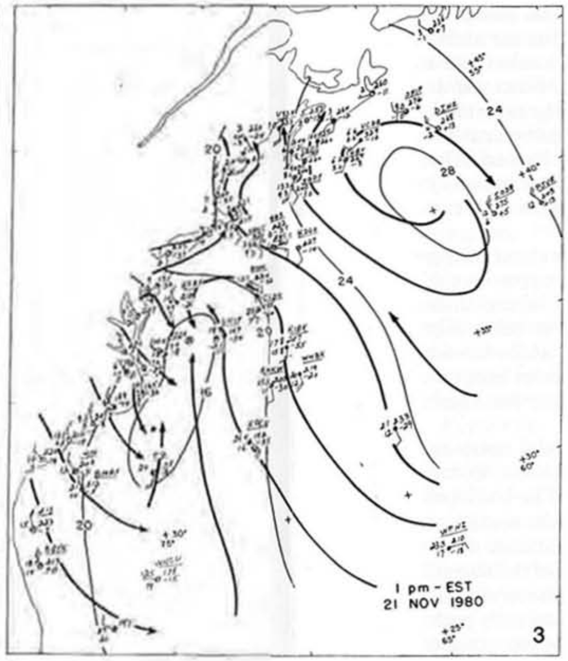
In order to fully understand these storms, we must first look aloft to much higher altitudes (Figures 2, 5, 8 and 11). Recent research provides a basis of hope for better accuracy in forecasting these storms. As illustrated by Figure 5, which displays the general direction of jet-stream flow at an elevation of about 5.5 kilometres (18,000 feet) at roughly the same time as that of Figure 4, there is no closed core that one sees when looking at a fully developed surface storm. There is, however, a distinct wave-like oscillation in the westerly jet stream, with a counter-clockwise kink of jet-stream direction round the wave trough.

This type of feature is called a Rossby wave and is always found at a modest distance west and above the surface storm as the lower level cyclone gets under way. These upper altitude Rossby waves tend to be long-lived features, unlike the storms they spawn at the surface. (In the case of the *Fairwind* storm, the pre-history of the Rossby wave (Figure 2) was unusually long, for its path extended back across North America, the Pacific Ocean and Asia to its origin as a weak slow-moving trough over central Europe on November 1!)

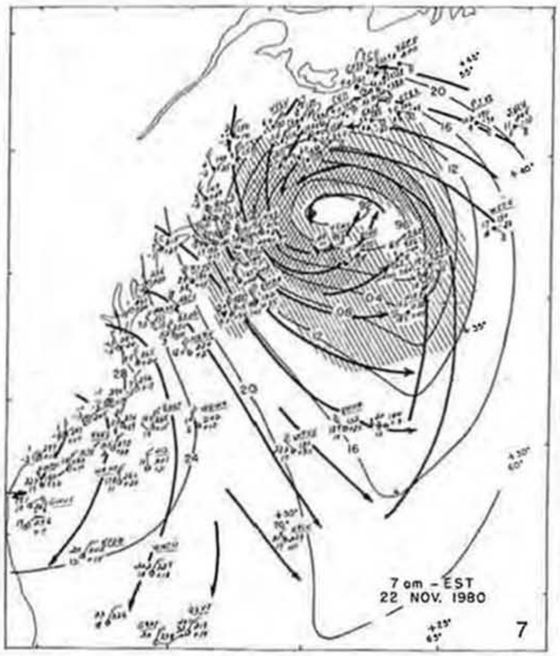
Surface cyclones are measured by the pressure of their central regions, the lower the pressure the more powerful the low. The strength of upper altitude Rossby waves is measured by a factor called vorticity. This is defined by scientists as twice the rotational rate of an imaginary disk that is spinning about a vertical axis and floating freely in the air, as viewed from space. In the

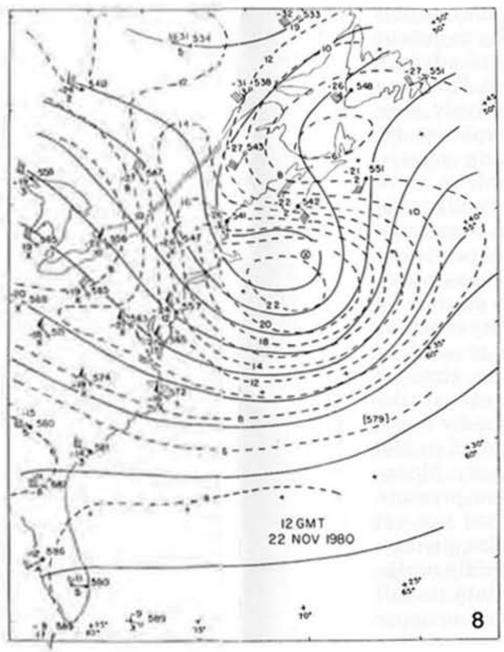


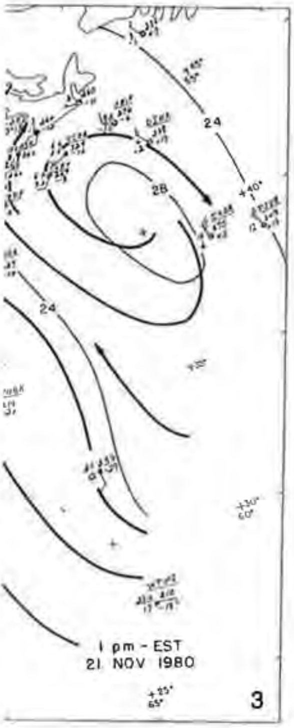


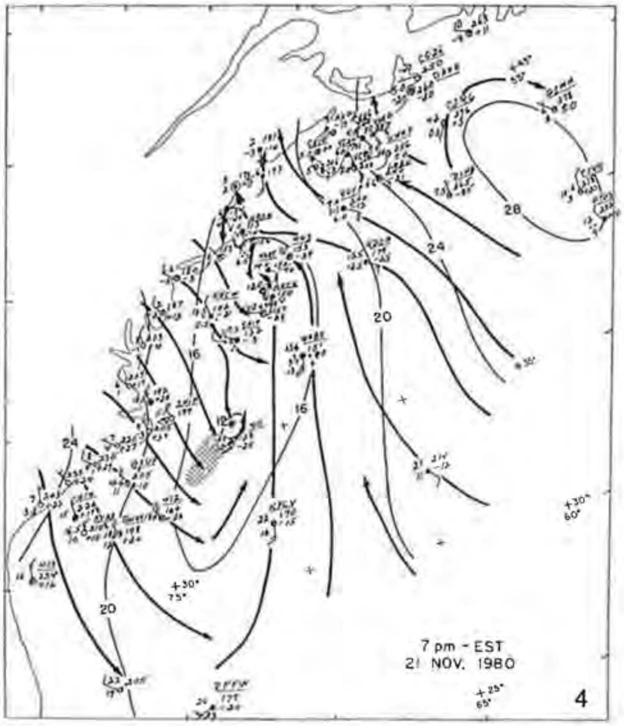


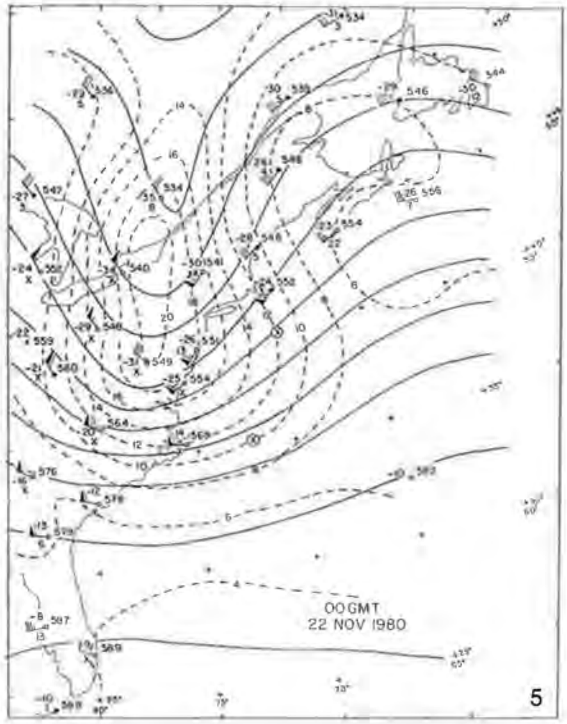
Figures 1–11 The sequence of surface and upper-air charts depicts the explosive development of the storm that battered the *Fairwind* and the *Sea Fever*. Figures 1, 3, 4, 6, 7, 9 and 10 show the surface conditions starting on November 21 at 7 a.m. EST (1200 GMT) and every 6 hours until 7 p.m. EST on November 22 (0000 GMT, November 23). The plotted data at each observing station follows the standard format (for decoding see *Chinook*, Vol. 8, No. 2). The thin solid lines are isobars that are labelled in millibars (for instance "20" indicates the 1020-mb isobar). The heavier solid lines with arrows are streamlines indicating the instantaneous airflow. Single hatching outlines surface winds of 35 knots or stronger, while the double hatching outlines those 50 knots or stronger.





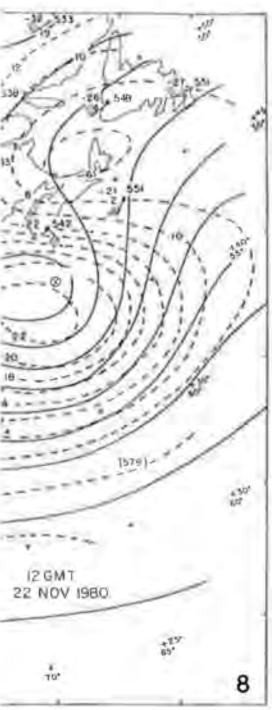


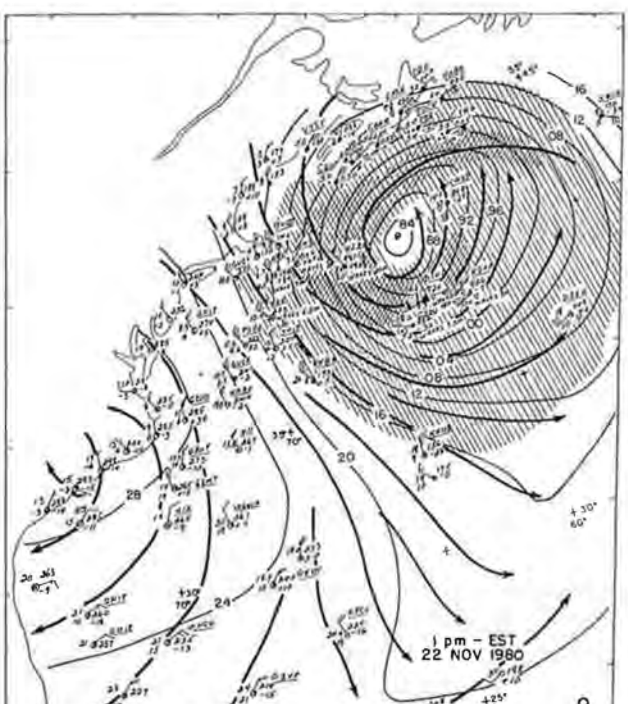


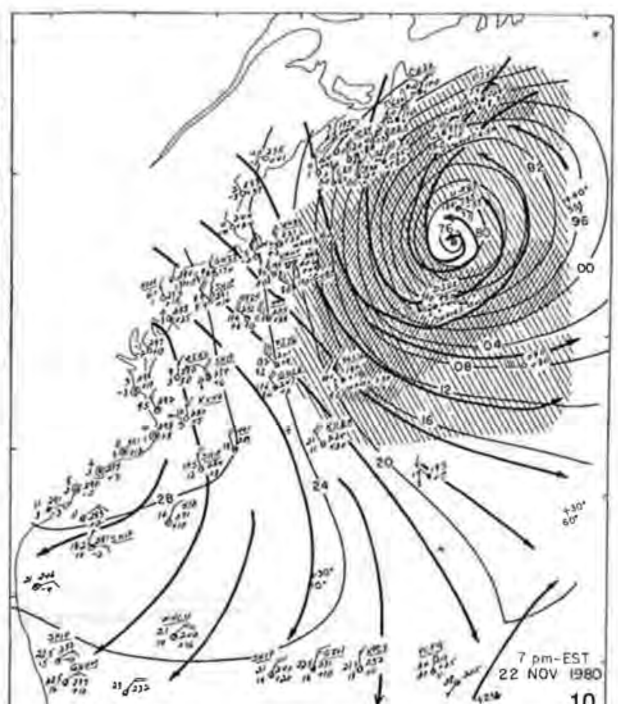


The upper-air charts (Figures 2, 5, 8 and 11) show the conditions at the 50-kPa (500-mb) level or at about 5.5 km. The solid lines are contours indicating heights of the 50-kPa level above mean sea-level. The dashed lines are curves of equal vorticity in units of 10^{-5} second^{-1}. The plotted data indicate the wind speed and direction, the height of the 50-kPa level in decametres (upper right), the temperature in degrees Celsius (upper left) and the difference between the temperature and dew point in degrees Celsius (lower left). The centres of the surface lows are indicated by the symbol ⊗.

The sequence clearly shows the intense development and the ultimately deep low on November 22 (7 p.m. EST), which had taken on the characteristics of a hurricane (Figures 10 and 11).







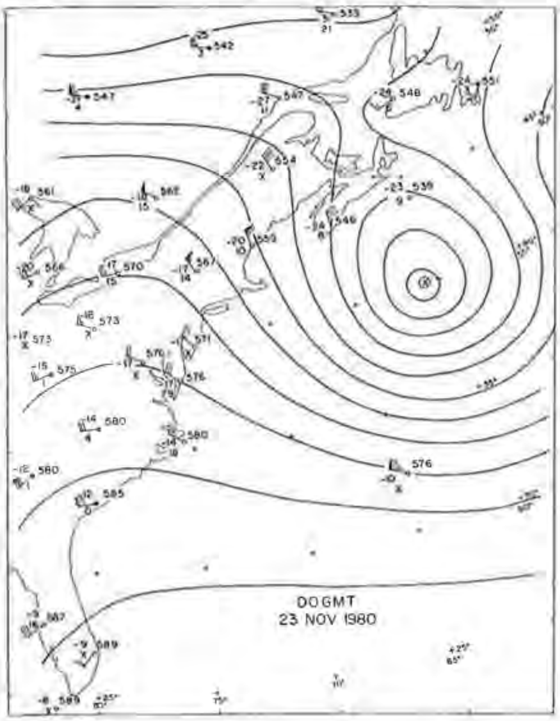


Figure 11.

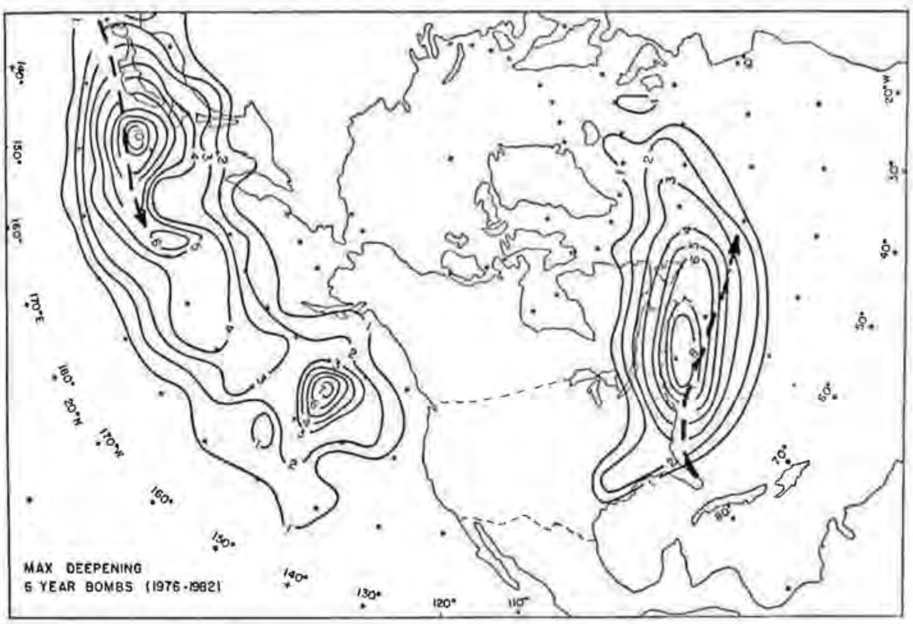


Figure 12 The maximum deepening positions of all of the 24-hour bombs (time period: 1200 GMT to 1200 GMT) for the years 1976–1982 (from Frederick Sanders and John Gyakum, 1980). The distributions of the maxima are well correlated with the positions of the warm ocean currents (solid dashed lines with arrows) such as the Kuroshio Current (Pacific) and the Gulf Stream (Atlantic) (after Paul J. Roebber, 1984).

case of the Rossby wave in Figure 5, its central vorticity of 0.001 rpm (= 20×10^{-5} second^{-1}) resulted half from the circulation of its winds and half from the rotation of the earth. This rpm number is low indeed when compared to, say, the rpm of a diesel engine. What makes this number impressive, however, is the sheer size of the associated wave. When a meteorological feature of this size has such a number, it is indicative of immense power.

When the winds aloft are moving through the sweeping turn of a Rossby wave, they have an effect on the air at the surface. The winds on the leading edge of the wave act like a vacuum cleaner, drawing up air from below. Since air is rising away from the surface, a low-pressure zone is formed. Higher pressure air from the surrounding area then rushes in to fill the low pressure. A storm centre is formed. The strength of the storm is the result of many factors but a key component is the ease with which the air at the surface can be lifted to higher altitudes.

A bomb can happen when the resistance to vertical lifting is small and the surface air readily climbs to upper levels. Cold air, on average, is more susceptible to lifting than warmer air, especially when it moves out over relatively warmer water and heat from the water is added at the lowest levels. These are just the conditions that exist from September on through the cold season, a prime time for bomb formation.

A detailed study of bombs occurring in the western Atlantic between January 1981 and November 1984 yielded a dozen storms that fit the bomb classification. The tracks of these strong bombs show a definite concentration along the Gulf Stream up to nearly latitude 40°N (see Figure 13 for the track of the storm, November 21–23, 1980). North of this, they tend to take a northeastwardly path across the strong contrast of sea surface temperatures at the north wall of the Gulf Stream, toward Newfoundland and the Canadian Maritimes. Maximum intensification occurs, on the average, while these storms are crossing the north wall and making the transition from cold slope water to warmer stream water. In this respect, as well as in their dependence on horizontal temperature contrasts, bombs differ from tropical hurricanes.

As the bombs cross the north wall their speed of advance is rapid, averaging some 35–40 knots, so that a mariner would have little opportunity to get out of the way without plenty of advance warning. The storm that hit *Fairwind* and *Sea Fever* was a relatively slow mover after the onset of explosive intensification, but the fishing vessels, once caught out, were unable to move out of the way and the slow advance of the cyclone only made the hurricane-force north winds unusually persistent and the accompanying huge seas lethal.

During one study of these storms, we found the upper-level vorticity centre or Rossby wave was always present at least 36 hours before the time of explosive storm development at the surface. At this time, the Rossby wave, on the average, was positioned in Nebraska just east of the Rocky Mountains, while the surface low-pressure centre on most occasions had not yet developed into a bomb. Subsequently, the surface storm moved rapidly northeastward while deepening into its full fury, as if urged by the oncoming upper Rossby wave centre, which passed close by to the south of the bomb as the surface storm neared the extent of its development.

What can the small-craft mariner do to avoid being in the dangerous vicinity of a fast-developing bomb? First, stay out of the susceptible waters at the time of year when the incidence of these storms is high. Although not without exception, bombs tend to occur in certain kinds of broad-scale conditions. If it is unusually cold along the coast and offshore, bomb prospects are especially dangerous. These cold conditions, of course, are undesirable anyway for voyaging in small craft, because of the icing hazard and general discomfort.

Remember, however, that the conditions that lead to a bomb can occur during the summer months, even though with far less regularity. And the "standard" type of mid-latitude storm develops in much the same way as a bomb. The differences are in the speed – bombs develop explosively in 12 to 24 hours – and in the final intensity of the storm – bombs usually produce stronger winds and steeper seas.

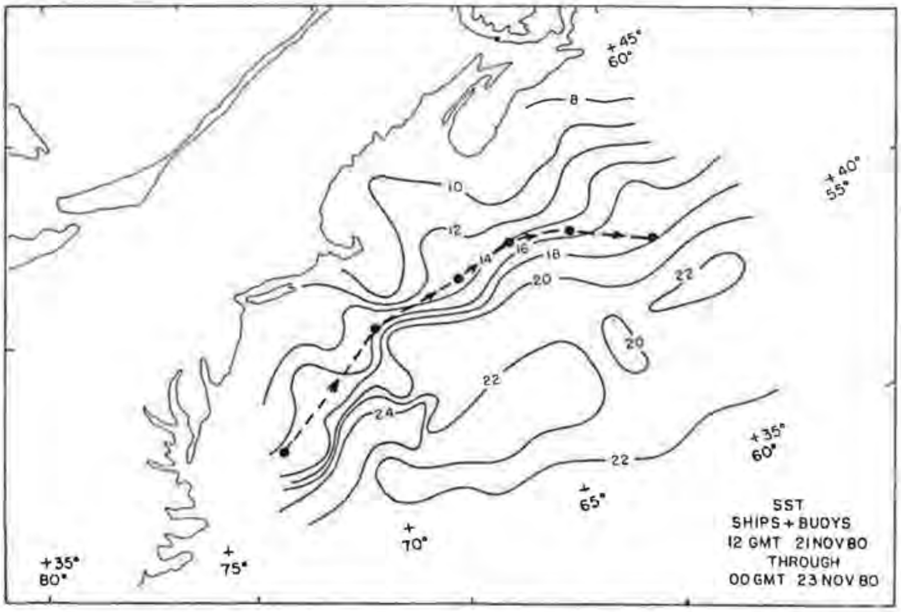


Figure 13 Sea surface temperatures (SST) from ship and buoy data for the period from November 21, 1980 (1200 GMT) to November 23 (0000 GMT) are depicted by the solid lines (°C). The dashed lines with arrows indicate the track of the storm.

If you have to be out there for one reason or another during the cold season, keep close track of the official forecasts. These are heavily based on computer prognoses that have been somewhat deficient in predicting the strength of bombs. Forecasters have had better luck identifying and tracking these storms, though. A new, and presumably improved, computer model is being added this season.

From most mid-Atlantic or northeastern ports, you would need assurance of at least three days of reasonable conditions to sail far enough south for safety from most bombs. The usual official marine forecasts do not extend this far in advance. It is well worth trying to obtain a special briefing from the nearest Weather Office or from a private weather service. These sources may be able to tailor forecast advice suitable for your particular needs and to keep in touch with you enroute.

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ACKNOWLEDGEMENT

It is gratefully recognized by *Chinook* that permission was received from Mr. Tim Queeney, Managing Editor of *Ocean Navigator*, to reprint this article (with a number of minor additions).

Frederick Sanders is an expert in synoptic-dynamical meteorology who is much sought after for his advice on and his deep insight into the development of weather systems and their effects. He was a weather forecaster with the U.S. Weather Bureau during the late forties and then taught at MIT where he has been a Professor since 1969. He co-authored *Descriptive Meteorology* with H.C. Willett. An avid deep-sea sailor, he is a member of the Eastern Yacht Club, Marblehead, Massachusetts.

RÉSUMÉ *Connaître le comment et le pourquoi de la formation d'une basse pression est de première importance pour les navigateurs. Pouvoir reconnaître les signes annonciateurs du mauvais temps peut permettre à un navire de l'éviter. Parmi les systèmes de basse pression des latitudes moyennes les plus dangereux, notons ceux qui se forment de façon explosive sur l'ouest de l'Atlantique Nord; ils traversent l'océan vers le nord-est en direction de l'Islande. On retrouve ces intenses tempêtes plus souvent en hiver; de la même famille que les tempêtes de nordet, on les surnomme "bombes" à cause de leur force et de leur intensification rapide. En étudiant leur formation on peut mieux comprendre les tempêtes moins intenses des mois plus chauds, mois de trafic maritime accru.*

Le 21 novembre 1980 l'une de ces "bombes" fait sombrer le Fairwind *et un marin du* Sea Fever *trouve la mort lorsqu'il est emporté par le vent. On observe des vents de plus de 70 noeuds et des vagues dépassant 20 m dans cette intense tempête en creusement.*

Pour définir une "bombe" on a utilisé une méthode arbitraire qui consiste à examiner les cartes météo journalières de l'hémisphère Nord et à identifier toutes les basses pressions, en mouvement, dont la pression centrale a baissé d'au moins 24 millibars en 24 heures. Ce test permet de trouver le taux de creusement critique ou, en d'autres mots, la baisse de pression au centre de la tempête, mesure importante car une baisse de pression entraîne un gain d'intensité.

Une étude, sur une période de trois ans à partir de septembre 1976, démontre que les bombes sont, presque exclusivement, un phénomène maritime et de saison froide.

On décrit les bombes selon leur occurrence globale et leur fréquence saisonnière. On discute en détail des facteurs dynamiques et thermodynamiques qui semblent influer sur et affecter la formation de ces tempêtes intenses.

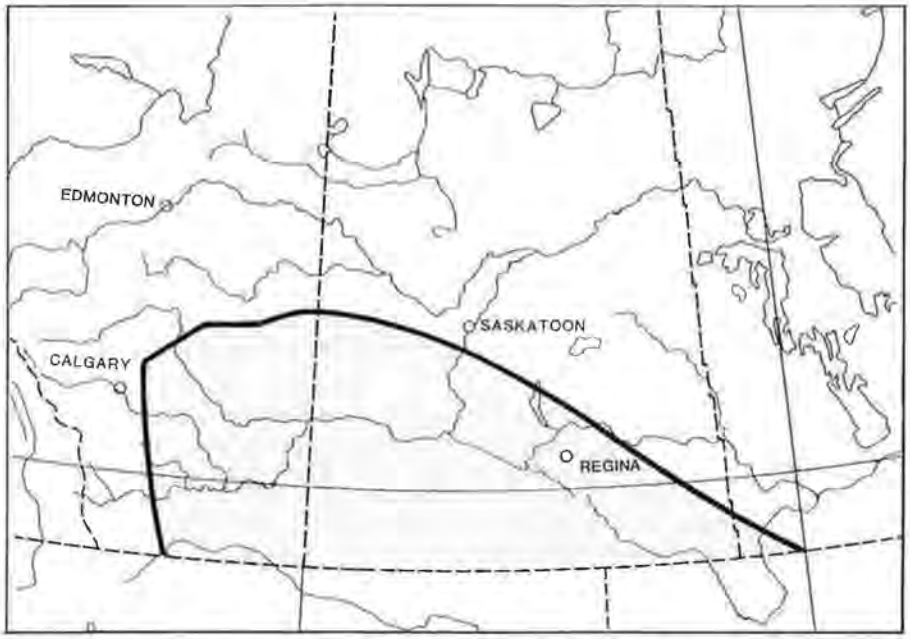
Les petits navires étant plus particulièrement sujets aux rigueurs de ces tempêtes doivent être avisés de leur formation. Il est important que toute personne qui prévoit un voyage en mer obtienne des informations d'un centre météorologique national ou d'un organisme privé compétent. Il est aussi important que les navigateurs se tiennent continuellement au courant des conditions météo présentes et prévues.

THE EARLY HISTORY OF CLIMATE AND AGRICULTURE ON THE CANADIAN PRAIRIES

by Barry Grace

Perhaps one of the most dramatic examples of man adapting to a new and severe climate and developing specialized practices to allow use of land for agriculture occurred in the Canadian and American west during the past 100 years.

One of the more famous explorers of western Canada, Captain John Palliser, travelled in the southern portion of the Canadian Prairies in 1857 and concluded that they would never be able to support a viable agriculture. Palliser delineated a triangular-shaped area where the climate and soils were unsuitable for agriculture. This area included most of southern Alberta, southern Saskatchewan, and southwestern Manitoba. However, Palliser's judgement was based on a superficial acquaintance with a vast area, mainly around its periphery in a drought year.



The shaded area depicts Palliser's "Triangle" (see map: Spry, 1959).

A much more important examination of the area was made by Professor John Macoun in the 1870s during a series of wet years. It was Macoun who demonstrated the importance of climate and especially summer rainfall to the Great Plains. It was Macoun's report that helped guide the Canadian Pacific Railway through the southern Prairies and led to the settlement of southern Saskatchewan and Alberta.

The major development that would change the course of western Canada's history and allow agriculture in the climatically restricted Prairies occurred by accident at Indian Head, Saskatchewan. There, in the early spring of 1885, farm horses were conscripted to haul supplies for the army that was suppressing the Rebellion of 1885. By the time the horses were released it was too late to plant a crop. However, the land was worked during the summer and the following year it produced an excellent crop of wheat despite the almost complete crop failure everywhere else. Angus McKay, the first superintendent of the Dominion Experimental Station at Indian Head, was so intrigued by this development that he launched a series of experiments with summerfallow as soon as his station was established. Out of these experiments came the development of the system of summerfallowing for the Canadian Prairies that turned Palliser's "Triangle" into the sometimes bread-basket of Canada. That system, and the development in 1907 of Marquis, an early ripening wheat that would consistently produce a crop in the short and unpredictable growing season of the Prairies, was decisive in the settlement of the West.

The system of summerfallowing consisted of rotating land use from one year to the next. Land was left uncropped for the summer. Soil moisture that accumulated in the soil from the previous winter's snow and the spring rains could be conserved by tilling the soil to prevent weeds from using the water. Although most of the summer precipitation was lost to evaporation, the reserve of soil moisture from the spring was generally left intact for use during the following crop year. Hence, at planting time the following spring, the soil had retained a considerable portion of the soil moisture reserves from the previous year as well as the moisture received during the current year. By alternating portions of the land between crop and fallow, a farmer was assured that he would have a crop both that year and the next. The farmer was reducing the risk of crop failure in the regions of low and unpredictable rainfall.

The summerfallow system had the added benefit of weed control and also increased the soil nutrient content through the mineralization of crop residues. Thus summerfallowing made it possible to grow bumper crops in regions where it was not possible without it. But summerfallowing was also the beginning of many of our soil erosion problems. By the late 1800s the practice of summerfallow was widespread on the Canadian Prairies. Excessive cultivation and burial of crop residues left the soil very susceptible to the high winds common on the Prairies.

In response to campaigns by the Canadian Government to settle the West through promises of free or very inexpensive land, settlers came to the Canadian West from all over the world. Experienced farmers from Ontario, the

United States, the British Isles and continental Europe flooded the Canadian Prairies. Between 1896 and 1914, the Dominion Government gave away millions of hectares of homestead lands while the railways and land companies sold millions of hectares more. The one characteristic the settlers had in common was that they had come from areas of high rainfall. The campaign to settle the Prairies was too successful. Too many farmers tried to make a living on too little land. In many agricultural areas of the world, 100 hectares was considered a large and productive farm. On the Prairies an economically viable farm required many more. The climate was much drier than the early settlers had experienced. As a result, unless there was an exceptionally wet season, productivity was low. The techniques of dryland farming had yet to be fully developed. Ironically, it was the best farmers who caused the most damage – those who followed the best scientific methods (by Eastern and European standards), who plowed deep, worked their fields well and maintained large fallow fields. It was their land that was most susceptible to wind and water erosion.

With the outbreak of World War I, more damage was done to the soil. The pressure to increase agricultural output in aid of the war effort resulted in the cultivation of 2 million more hectares in 1915 than in the previous year. During the next 4 years an additional 5 million hectares were added to cultivation. Much of this land was marginal or submarginal, and should never have been broken. Since the adoption of summerfallow tillage practices on the Prairies was now widespread, some farmers began to see the winds blowing their topsoil away. By 1914, drifting was extensive throughout the chinook belt in the vicinity of Lethbridge in southern Alberta, where high winds are the rule in the fall, winter and spring. It was here that the frequent periods of wind erosion led to the development and widespread practice of strip farming about 1918. Other areas of the Prairies were as yet unconcerned.

Crop failures in 1917, 1918, and especially 1919, were severe. Climatic data taken in 1919 at the then recently established Dominion Experimental Station at Lethbridge indicate the worst drought observed at that location, a record that stands even to this day.

When blowing soil became common, serious doubts were raised about the wisdom of settling the country at all. Both Alberta and Saskatchewan established commissions to study the problems of dryland farming. Recommendations from the commissions included the use of more irrigation as a result of the success that Alberta was having in the Lethbridge area, the establishment of a special experimental farm at Swift Current to make scientific investigations of dryland farming problems, and the establishment of an agricultural extension service that would be staffed by trained agrologists to spread the latest information from the scientists to the farmers. The Dominion Government moved immediately to establish the Experimental Farm at Swift Current. It was 30 years later, however, that the equally important recommendation of establishing an extension service in each of the Prairie Provinces was completed.

During the early 1920s, the problems of overpopulated farmland eased as farmers abandoned their land in large numbers. For example, the 1926 census counted more than 10,000 abandoned farms in southern Alberta alone. With a

Wind erosion of soil resulted in many farmers abandoning their farms in western Canada.

Man-made deserts of the 1930s threatened an estimated 7 million hectares of Prairie land.

Blowing soil, April 14, 1935.

larger land base, good prices and the favourable climate of the late 1920s, farmers paid off the debts they had accumulated prior to 1922 and with easy credit increased their land holdings and began the big change from horses to tractors and combines. Problems of soil erosion seemed to disappear. Such problems were considered to be important only at the Dominion Experimental Stations and Farms at Lethbridge, Swift Current, Indian Head and Brandon where scientists were pioneering research on dryland farming techniques that would be applicable to the Prairie climate and soils.

The blowing soil of the western Canadian desert began in 1929 on parched summerfallow. Each year the area expanded until, by 1937, the entire Palliser Triangle was threatened, an estimated 7 million hectares – a quarter of all the arable land in Canada. The man-made deserts of the 1930s in western Canada were not exclusively the result of the summerfallow system. Indeed, summerfallow remains to this day a valuable agricultural practice both in Canada and in other countries where dryland farming occurs. However, it must be practised with other dryland techniques to prevent desertification.

Through the efforts of a small group of very dedicated people the problems of massive soil erosion were reversed and the Canadian Prairies were saved for agriculture. Among the handful of people who are credited with saving the Prairies are Dr. Asael Palmer of Lethbridge for promoting trash cover fallowing, C.S. Noble for developing the Noble blade plow to reduce residue burial during cultivation, Dr. Lawrence Kirk for developing Fairway crested wheat grass at the University of Saskatchewan to stabilize drifting areas, and Sidney Barnes for his work on the effect of wind on drifting soil. The developments and experiments of these and other men led to the publication of the Hopkins-Barnes-Palmer-Chepil manual on Soil Drifting Control in the Prairie Provinces in 1935. This was the best appraisal of the problem, requiring solutions by the Experimental Farms and was based largely on the imaginative and painstaking research at Lethbridge and Swift Current. In that same year, the Prairie Farm Rehabilitation Authority was formed to become the instrument to contain the desert in western Canada.

To this day, research on climate and farming techniques continues at the Research Stations across the Prairies. Modern and sophisticated tests and experiments are continually being evaluated. Aspects of tillage, water conservation, and microclimate are only a few of the matters that are being examined in an effort to improve productivity in an area and climate that was once thought to be incapable of supporting agriculture.

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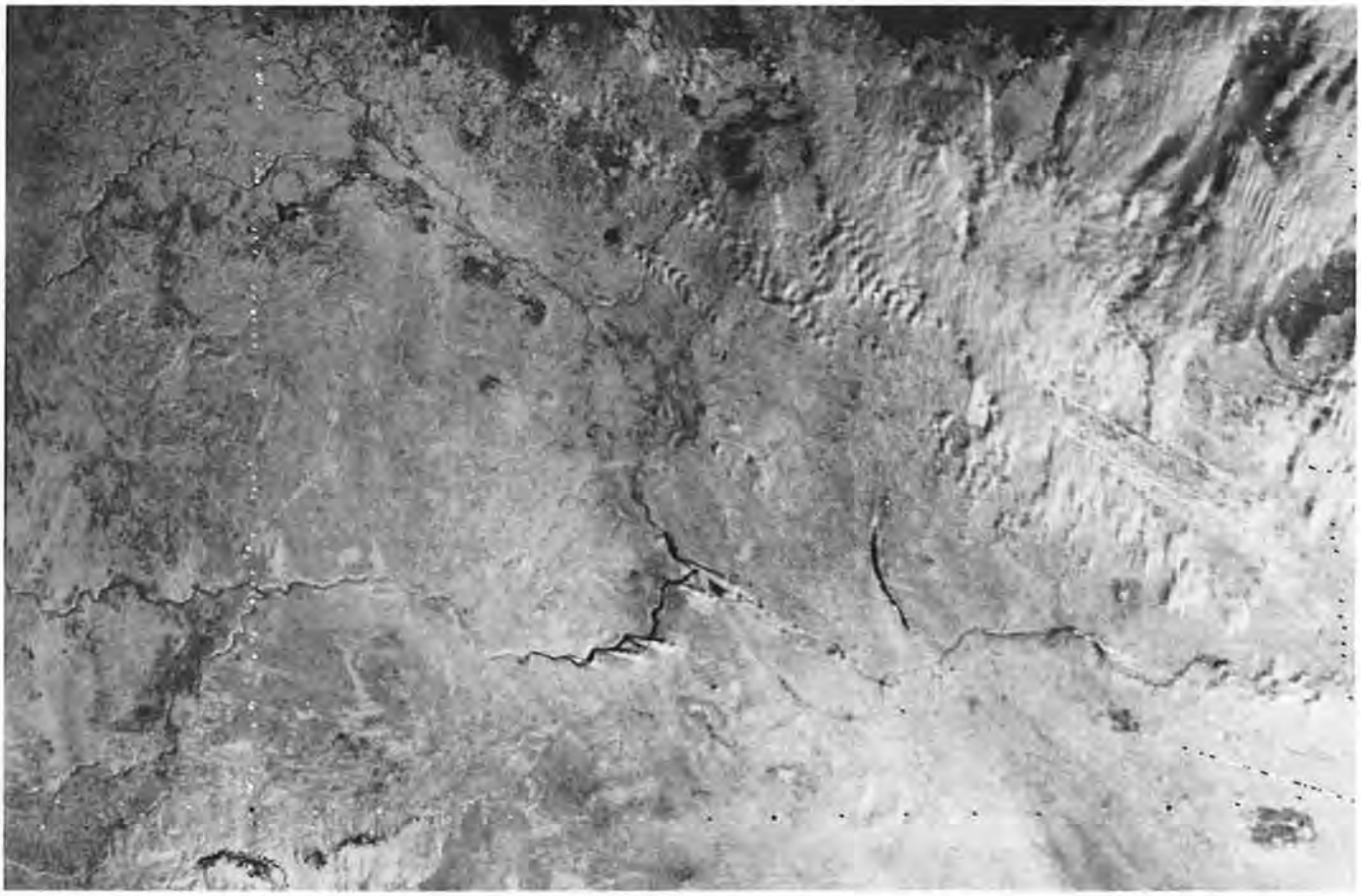
Photograph credits: Lethbridge Research Station Archives.

RÉSUMÉ *Cette petite histoire du climat et de l'agriculture dans les Prairies canadiennes débute par l'analyse des premières évaluations faites dans le but d'utiliser la région pour l'agriculture. Quelques tentatives dans les années 1880 réussissent. L'introduction des jachères d'été fait des Prairies du sud, au début du siècle, le grenier du Canada. L'alternance de culture et de jachère permet au sol de garder une bonne humidité. En plus, le risque de mauvaises récoltes est diminué dans les régions où les pluies sont imprévisibles.*

Au début du siècle les colonisateurs venus de plusieurs parties de l'Europe établissent des fermes dans la région. Cependant, plusieurs de ceux-ci n'ont aucune expérience de ce nouveau climat, étant plutôt habitués à un climat plus modéré et humide.

De fortes sécheresses, les mauvaises récoltes et l'érosion du sol entraînent des études poussées sur les problèmes de culture en terrain sec. Au cours des années, les efforts continus de scientistes dévoués permettent de mieux comprendre l'impact du climat sur l'utilisation des sols pour l'agriculture, les stratégies et les techniques d'exploitation, la réduction de l'érosion, et la possibilité d'une désertification.

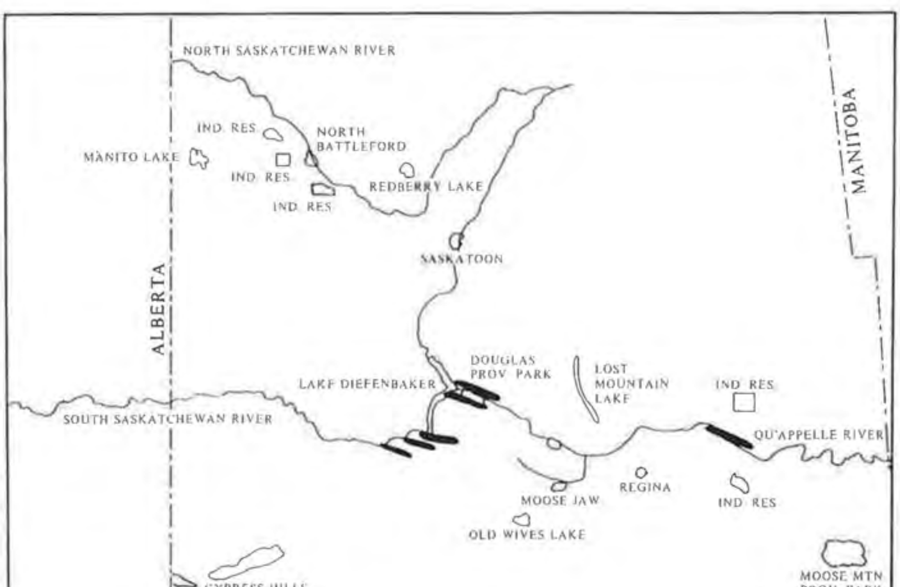


LAKE EFFECT ON THE FRIGID PRAIRIES

by Hans VanLeeuwen

Winter arrived on the Canadian Prairies at the end of October 1986 and remained well entrenched during November. From November 6 onward an outbreak of frigid Arctic air moved southward and during the following three weeks the three Prairie Provinces and the northern U.S. Plains States experienced well below normal temperatures.

The satellite image shown illustrates surface features as seen by the U.S. NOAA-10 polar-orbiting satellite on November 12 at 1537 GMT (0837 MST or 0937 CST). The image is for the near infrared (NIR) part of the radiation spectrum (wavelength interval: 0.73–1.1 μm). White on the image corresponds to regions of high radiation flux as seen in the returns from high albedo and/or warm areas. Black corresponds to regions of low radiation flux, as seen



in returns from low albedo and/or cold areas. An advantage of the NIR image is the strong and noticeable contrast between warm, high albedo areas and cold, low albedo areas.

On November 12, southern Saskatchewan was under the influence of an intense high-pressure area that was centred over Montana. The surface winds in most of southern Saskatchewan were from a west-northwesterly direction at 15 to 20 km/h, while the temperatures were generally between −22 and −24°C.

The last two weeks of October had well above normal maximum temperatures (15 to 23°C). This, of course, delayed any cooling of the larger water bodies in Saskatchewan, such as Lost Mountain Lake, Lake Diefenbaker, the North and South Saskatchewan Rivers and the Qu'Appelle River. The very cold and unseasonable November air overlying these much warmer water bodies thus provided for some unusually strong vertical temperature gradients in the lowest levels of the atmosphere. Very clearly noticeable on the image are the darker (warm) water bodies and – as illustrated in the accompanying sketch – the convective cloud plumes or cloud streets (parallel to the prevailing air flow) coming off Lake Diefenbaker and the Qu'Appelle River. The cloud streets are frequently observed in winter around such areas as the Great Lakes, where they are the producers of significant snowfalls in the so-called snow-belt areas. Forested areas, such as Moose Mountain Provincial Park and the Cypress Hills, which have low albedos, show up as darker areas on the image. Interestingly, several Indian Reservations are clearly delineated, since most of them are also predominantly forested. Both Regina and Moose Jaw can be spotted on the image, as well as the shallow, and likely partially frozen, Old Wives Lake.

A student of Geography, using a detailed topographical chart and a road map, would undoubtedly be able to spot and identify many more interesting features, such as Willow Bunch and Big Muddy Lakes, the Frenchman River, Wood Mountain, the Vermilion Hills and the Missouri Coteau.

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(Chronological Order)

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.

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- 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

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- stimuler l'intérêt du public et l'aider à mieux comprendre les effets du climat, du temps et des océans sur la société et sur l'économie du Canada;
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