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Rime Icing on Mt. Kobau

Meteorological and engineering investigations are continuing at the proposed site of the Queen Elizabeth II Telescope. The pictures show the rime ice that had built up on a one-hundred foot tower over the twenty-four days prior to December 8, 1966. During that period, at least ten days had water-droplet fogs at sub-freezing temperatures.

The observer was H. Lothian of A.B. Sanderson and Co. Along with many others across Canada, he makes reports on icing of structures like towers, wires, etc., that cause damage or are special in some other manner. Members of the Society are asked to send complete reports of any storm in which icing contributes to the breaking of wires, poles, or the like.

Snow and Ice Section,
Division of Building Research,
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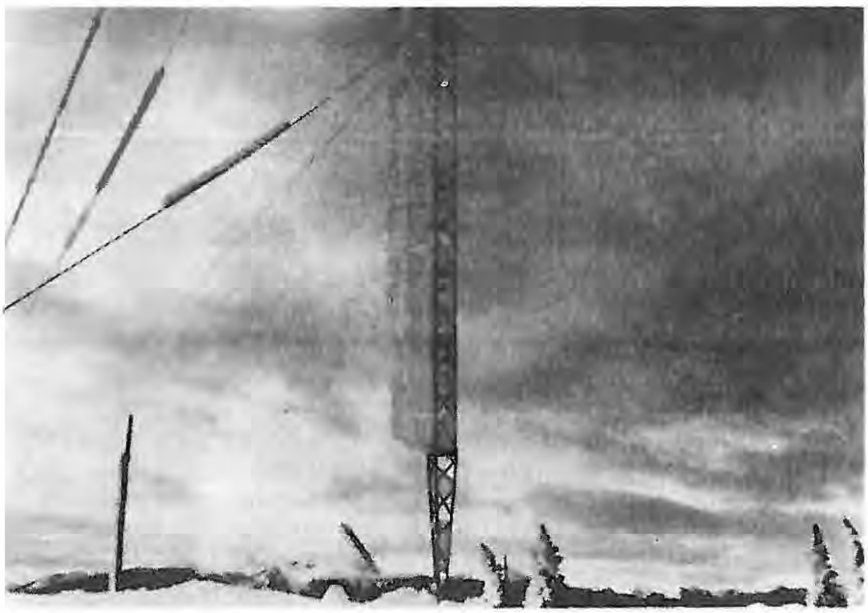
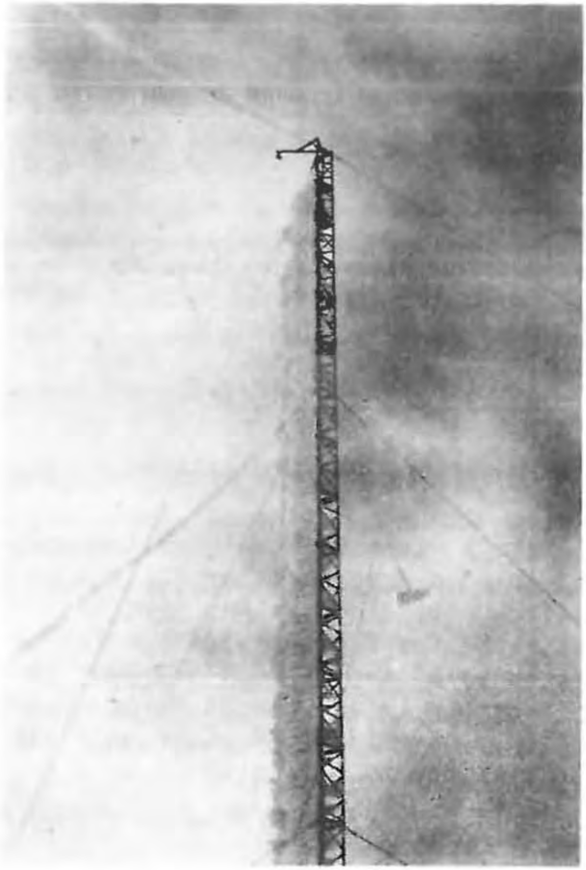




THE FREQUENCY OF WINTER CHINOOKS IN ALBERTA

by

Richmond W. Longley

University of Alberta

Abstract

A study was made of winter temperatures to determine the frequency of chinook days in Alberta. The resulting pattern shows a maximum frequency along a line just east of the front range of the mountains, with the frequency decreasing slowly eastward. But a careful analysis of the Calgary-Red Deer-Drumheller triangle shows that the frequency is influenced by local topography and that the warm air at times overrides a pool of cold air in a valley to appear at high elevations to the east.

1. Introduction

A common subject for discussion among residents of the province of Alberta concerns itself with the frequency of chinooks. It is recognized that the warm air of these chinooks comes most frequently through the Crowsnest Pass and eastward along the Old Man River. But other parts of the province bask occasionally in the mild air that flows over the mountains from British Columbia.

The synoptic features of the weather map that bring a chinook to Alberta have received much study. Pacific air is carried eastward around a ridge of high pressure located in the mountain areas of northwestern United States. Losing its moisture on the ranges of British Columbia, the air moves down the slopes of western Alberta, bringing relatively high temperatures. The cold Arctic air is sometimes driven eastward and northward. At other times the mild air overrides the colder air, and the full effect of the chinook is not felt at the ground. Under these conditions, the temperature at 2000 ft above ground may be several degrees above freezing while at the surface it is 20° or lower. (Temperatures will be quoted in degrees Fahrenheit unless otherwise noted.) Even under these conditions, the surface air is considerably warmer than usually found in the Arctic air in Alberta. This partial effect of a chinook makes it difficult to say clearly whether or not a chinook has reached a specific locality.

2. Definition of a Chinook

In order to make a comparison between localities, it is necessary to establish a criterion on which to base figures. The criterion used in this study is the occurrence of a maximum temperature 40° and above, and the study was restricted to the winter months of December, January, and February. In reality, then, this is a study of the relative frequency of maximum temperatures in winter of 40° and over. Accustomed to winter temperatures reaching 50°, residents of southern Alberta will consider that the temperature selected is too low. People to the north and northwest bask in winter temperatures of 30 to 35° with sunny skies and west winds, and recognize that warm air has come over the mountains. But snow melts very slowly unless the temperature in the thermometer screen has reached 40° because of the normal inversion of temperature near the surface. The figure chosen is a compromise, but gives an approximate figure of the number of days when snow on the ground will decrease appreciably.

3. Data and Analysis

The period examined was from 1931 to 1965 using the winter months of December, January and February. The number of days during each month on record when the temperature reached 40° was recorded. The number of stations with a complete record for the period is small. When the record for a station gave data for 30 years or over for any specific month, the average was computed and taken as the mean number of chinook days for that month.

To discard other records would have meant that available information was not used. On the other hand, one should not accept without question the arithmetic means. The number of days with 40° temperatures is not normally distributed; the inclusion or exclusion of a year with an abnormally high number could give a distorted picture. When a partial record was available, the frequency of chinook conditions during the months of record was compared with the frequency of similar conditions for those same years at some adjacent long-term station, and the mean number of days during the month was adjusted accordingly.

4. Frequency of Chinook Days

The mean number of days for each of the three months for 139 stations in Alberta was determined by the methods described, and from these the total number of days per winter was determined. The list of those stations with 10 years or more of record, their location, the number of years of record, and the mean number of chinook days are given in Table 1. Thirty-eight stations had records of less than 10 years. Even though the means were adjusted as described, the computed values for these stations were used with caution. The mean numbers of chinook days for all stations were plotted on a map, and isolines drawn. The result is shown in Fig. 1. Data are scanty in the northern half of the province except in the upper Peace River and around Lesser Slave Lake. There are also few data in the foothills of the Rockies north of the Bow River. Isolines for these areas must be accepted as tentative.

The most prominent feature of the map is the region of maximum frequency along the Old Man River from Fort Macleod to Taber. Here almost 40 per cent of the days have temperatures reaching 40°. The 35-day isoline encloses Raymond, Magrath, Fort Macleod, Lethbridge, Coaldale, Claresholm and Lyndon. On the other hand, it is apparent that any place in Alberta where people reside has on the average one or two days each winter when the temperature reaches 40°.

Another feature of the map is the band of higher frequency along the foothills of the Rockies. This shows itself along the Old Man River. Pincher Creek, with a mean of 29 days, and Cowley with 31 days have fewer chinook days than the Lethbridge area. The frequency drops to the east from 34 at Taber to 24 at Medicine Hat. The band of maximum frequency is even more marked along the Bow River than along the Old Man River. Coming down the river, Lake Louise has only 3 days, Banff has 10 days, Anthricite 10 1/2 days, Exshaw 19 days, and Kananaskis 29 days. Calgary, with 27 days and Strathmore and Gleichen with 22 days are east of the maximum. A short record at Glenmore Dam in southwest Calgary suggests that here the frequency is 1 1/2 days more than at the airport in northeast Calgary. Again, further north, Entrance on the Athabasca with 26 days has more frequent 40° weather than Jasper 40 mi to the southwest with 14 days or Hinton 10 mi to the east with 23 days.

One reason for a difference in temperature is a difference in elevation. As the air descends the slope of the mountain, it will warm about 1°F/200 ft. Air of 40° at Fort Macleod would have passed Cowley, 750 ft higher, at a temperature of 36°. To take warming into account, one should adjust this temperature base for altitude. But this is not the only reason for an increase in the frequency of chinooks as one goes eastward from the mountain valleys to the plains. Kananaskis and Banff are at approximately the same altitude, and Entrance is only 200 ft lower than Jasper. On many occasions, the warm air passes aloft over the air of the mountain valleys, and descends to the earth's surface to the lee of the mountains. Crowe et al (1962) noted that the foehn winds in Manitoba showed these characteristics. Rivers and Neepawa, to the southwest of Riding Mountains, sometimes remained in cold air while air from aloft descended to the surface at Dauphin, northeast of Riding Mountain. Based on the observations along the Bow River, the location of this downward current is well marked. It apparently descends to the earth frequently in the eight miles between Exshaw and Kananaskis. The locations of the band of high frequency between the Bow and the Athabasca Rivers is unknown because of the lack of winter observing stations.

As the chinook air passes eastward, either one of two reasons will keep surface temperatures from rising to 40°. At times, the cooling effect of the cold ground or the sublimation of the snow cools the warm air near the surface as it moves eastward. At other times the cold Arctic air remains at the surface and the mild Pacific air is forced aloft above the frontal surface.

5. Upper Air Observations

Information on upper air temperatures over Alberta is scanty. Observations have been taken at Edmonton and at Fort Smith (60°N, 112°W) on the northern boundary twice daily, but in the south where chinooks are most frequent there is no information.

Data for Edmonton were examined for the 23 winter months from January 1959 to February 1966 inclusive. During these months, the temperature over Edmonton was above freezing at some level at the time of either the morning or evening observation on 277 days, or 32 per cent of the days. Of these 277 days, the maximum at Edmonton reached 40° on 89 days, i.e., on 13 per cent of all days, or 32 per cent of days with warm air aloft. For this sample period, the mean number of winter chinook days at Edmonton was 11.7 compared to 11.0 for the total period 1931-1965, thus indicating that the sample was not far from normal. Based on the sample, we find that at Edmonton, and presumably throughout central Alberta, chinook winds cause above-freezing temperatures on one day in three but on only one-third of these days does the surface temperature reach 40°.

6. Anomolies in the Frequency of Chinook Days

A study of the frequency of chinook for individual stations reveals some anomolies. One of these is found at Rocky Mountain House. A station established in 1915 was replaced by another not far distant in 1945. There was no overlap by which the records for the two stations could be compared, but data on chinook days indicates a marked difference between the two stations. The difference is seen by comparing the number of chinook days at Rocky Mountain House with those at Olds 60 mi to the southeast and Wetaskiwin 70 mi to the northeast. These are the two closest stations with complete records. On the basis of 26 months, the initial station at Rocky Mountain House has on the average 9.6 days with maxima 40° or over. Using the same 26 months, the average for Olds was 26.8 days, and for Wetaskiwin 16.4 days. Using the 64 months for which records for the second station at Rocky Mountain House were available, Olds had an average of 20.5 winter days with chinooks and Wetaskiwin 11.3 days. Yet at the Rocky Mountain House station, the average number for the winter was 20.9 days. Thus the new station reaches 40° as frequently as Olds, but Olds had 40° weather almost three times as often as the old station.

The density of stations in the Drumheller-Red Deer-Calgary triangle permits a closer study of the relative frequencies and reveals some further anomolies. Fig. 2 presents a map of this region with its topography and the location of the stations in the area. Three Hills, Olds, and Calgary have complete records. The other stations have records varying from 4 to 34 years.

The character of the anomolies is shown by a comparison of the frequency of chinook days with Three Hills. For each station of the district, statistics for those months when observations were taken were compared with the corresponding statistics at Three Hills. From these comparisons, a figure giving the difference between number of chinook days at the station and the number of chinook days at Three Hills was determined. For Olds and Calgary, the differences can be found from Table 1. For the other stations the differences are for different periods. It is not obvious that these figures are comparable, but the data from Hillsdown and Pine Lake, only a few miles apart, indicate that the error is not large. Hillsdown's record for 23 years during a period of relatively few chinooks, and the mean number at Three Hills was 14.2. Pine Lake, with only five years, 1961-65, has had observations during a period of more frequent chinooks, the mean number for Three Hills being 22.6. Both places had an excess of chinook days over Three Hills, of amounts of 1.8 and 1.1 days respectively.

The excesses or dificits of the number of chinook days over those at Three Hills are plotted on Fig. 3, and tentative isolines are drawn. The figure shows the normal gradient from southwest to northeast, but anomolies appear that must be associated with the local topography. The high land in the vicinity of Hillsdown must frequently penetrate the inversion to have mild temperatures when the surrounding areas are cold. The flows within valleys are dependant upon the orientation. The valley of the Three Hills Creek opens to the south and the warm air moves at times up this valley to give higher temperatures at Three Hills than at Trochu Equity or Acme. It is probably that the same flows are found in other valleys. In contrast, the valley of the Red Deer River near Penhold opens to the northeast. Warm air moving over the ridge to the southwest leaves a pool of cold air in the valley bottom where Penhold observing station is located. In such a situation the frequency of 40° weather at Penhold is less than on the surrounding hills. It is probably that the influence of the topography shown in Fig. 2 is even greater than that indicated by the isolines but the evidence is lacking. What information is available shows that topography results in differences in the frequency of high temperatures even as it does in the occurrence of very low temperatures. Mean temperatures give some evidence of this. Mean January maximum temperatures for 1931-1960 are: Penhold, 16.4; Olds, 22.4; Red Deer, 17.8; Hillsdown, 19.5; Three Hills, 17.8.

Conclusions

The study has clarified the idea that chinook days are most frequent in a band to the east of the Rocky Mountain range. At times the warm air sweeps over the mountain and descends on the eastern slopes without having its full effect at the surface in the mountain passes and valleys. Flowing eastward, the air cools by contact with the earth or overrides cold air so that the frequency drops as one leaves the foothills area. But the study has shown that local topographical features cause at times local pools of cold air to remain even when further east the warm air can at times reach the earth's surface again. A knowledge of these flows and of the resulting temperature distributions could be obtained only through a study of the microclimate of the district, a study which cannot be made using only the official records.

References

Crowe. B.W., C.L. Kuchinka, and W.A. Ross, 1962; The Occurrence of Foehn Winds in Manitoba. Meteorological Branch, Department of Transport, Tec. Cir. 433.

TABLE I

Average number of days during December, January and February with temperatures above 39°F, 1931 - 1965.

Station	Location North Latitude	West Longitude	Years Record	No. of Days
	North Saskatchewan River Basin			
Alliance	52	112	12	9
Calmar	53	114	35	14.4
Camrose	53	113	27	11
Consort Wades	52	111	12	5
Coronation	52	111	23	8
Edmonton Ind.	54	114	35	11.0
Edmonton Namao	54	113	10	9
Elk Point	54	111	33	4.9
Hughenden	53	111	26	9
Lloydminster	53	110	14	4
Naco	52	111	32	7.4
Newbrook	54	113	10	7
Ranfurly	53	112	35	6.2
Rocky Mtn House I	52	115	9	8
Rocky Mtn House II	52	115	21	23
Sedgewick	53	112	15	8
Sion	54	114	26	13
Stettler	52	113	29	12
Thorhild	54	113	24	7
Thorsby	53	114	25	15
Vermilion	53	111	29	5
Viking	53	112	30	6.2
Wastina Hemaruka	52	111	31	6.0
Wetaskiwin	53	113	35	13.4
	Red Deer River Basin			
Alix	52	113	17	21
Empress	51	110	12	11
Hanna	52	112	28	13
Hillsdown	52	114	23	17
Jenner	51	111	29	14

. . . . . TABLE I Continued

Station	Location North Latitude	West Longitude	Years Record	No. of Days
	Red Deer River Basin			
Lacombe	52	114	28	15
Olds	52	114	35	22.9
Penhold	52	114	27	13
Pollockville	51	112	13	10
Red Deer	52	114	21	15
Springdale	53	114	22	15
Three Hills	52	113	35	15.8
Trochu Equity	52	113	11	10
	South Saskatchewan River Basin			
Brooks	51	112	35	21.0
Caldwell	49	114	21	27
Calgary	51	114	35	27.0
Cardston	49	113	35	34.1
Carway	49	113	26	27
Claresholm	50	114	17	36
Fort Macleod	50	113	34	35.8
Gleichen	51	113	34	21.8
Hays	50	112	12	24
High River	50	114	34	33.5
Lethbridge	50	113	35	35.7
Magrath	49	113	11	36
Medicine Hat	50	111	35	24.2
Pincher Creek	50	114	26	29
Raymond	49	113	16	36
Strathmore	51	113	13	22
Suffield	50	111	16	19
Taber	50	112	18	34
Turner Valley	51	114	15	32
Vauxhall	50	112	28	28

. . . . . TABLE I Continued

Station	Location North Latitude	Location West Longitude	Years Record	No. of Days
	South Saskatchewan River Basin			
Vulcan	51	113	10	24
Whitla	50	111	12	23
	Milk River Basin			
Manyberries	49	111	35	20.8
	Rocky Mountains			
Anthricite	51	116	25	11
Banff	51	116	34	9.8
Beaver Mines	49	114	24	27
Cowley	50	114	25	31
Exshaw	51	115	11	19
Jasper	53	118	29	14
Kananaskis	51	115	25	29
Lake Louise	51	116	34	2.9
Lundbreck	50	114	24	30
Nordegg	52	116	23	12
Pekisko	50	114	29	27
Waterton H.Q.	49	114	13	28
	Athabasca River Basin			
Athabasca	55	113	32	8.6
Camsie	54	115	34	13.7
Edson	54	116	35	17.2
Embarras	58	111	19	2
Entrance	53	118	30	26.6
Fort McMurray	57	111	35	5.0
Grouard	56	116	11	7
Heldar	54	115	10	13
High Prairie	55	117	33	11.4
Kinuso	55	115	11	12

Station	Location North Latitude	West Longitude	Years Record	No. of Days
	Athabasca River Basin			
Lac la Biche	55	112	21	7
Meanook	55	113	20	10
Moon Lake	53	115	13	19
Peavine	54	115	17	16
Slave Lake	55	115	30	8.6
Wagner	55	115	21	11
Whitecourt	54	116	23	14
	Peace River Basin			
Beaverlodge	55	119	35	12.6
Berwyn	56	118	14	6
Buffalo Head Prairie	58	116	22	5
Almsworth	55	120	15	14
Fairview	56	118	34	6.7
Fort Chipewyan	59	111	13	2
Fort Vermilion	58	116	35	2.3
Grande Prairie	55	119	28	9
Keg River	58	118	29	8
Peace River	56	117	13	7
Rycroft	56	119	19	13
	Iron River Basin			
Cold Lake	54	110	13	4
Iron River	54	111	31	5.3

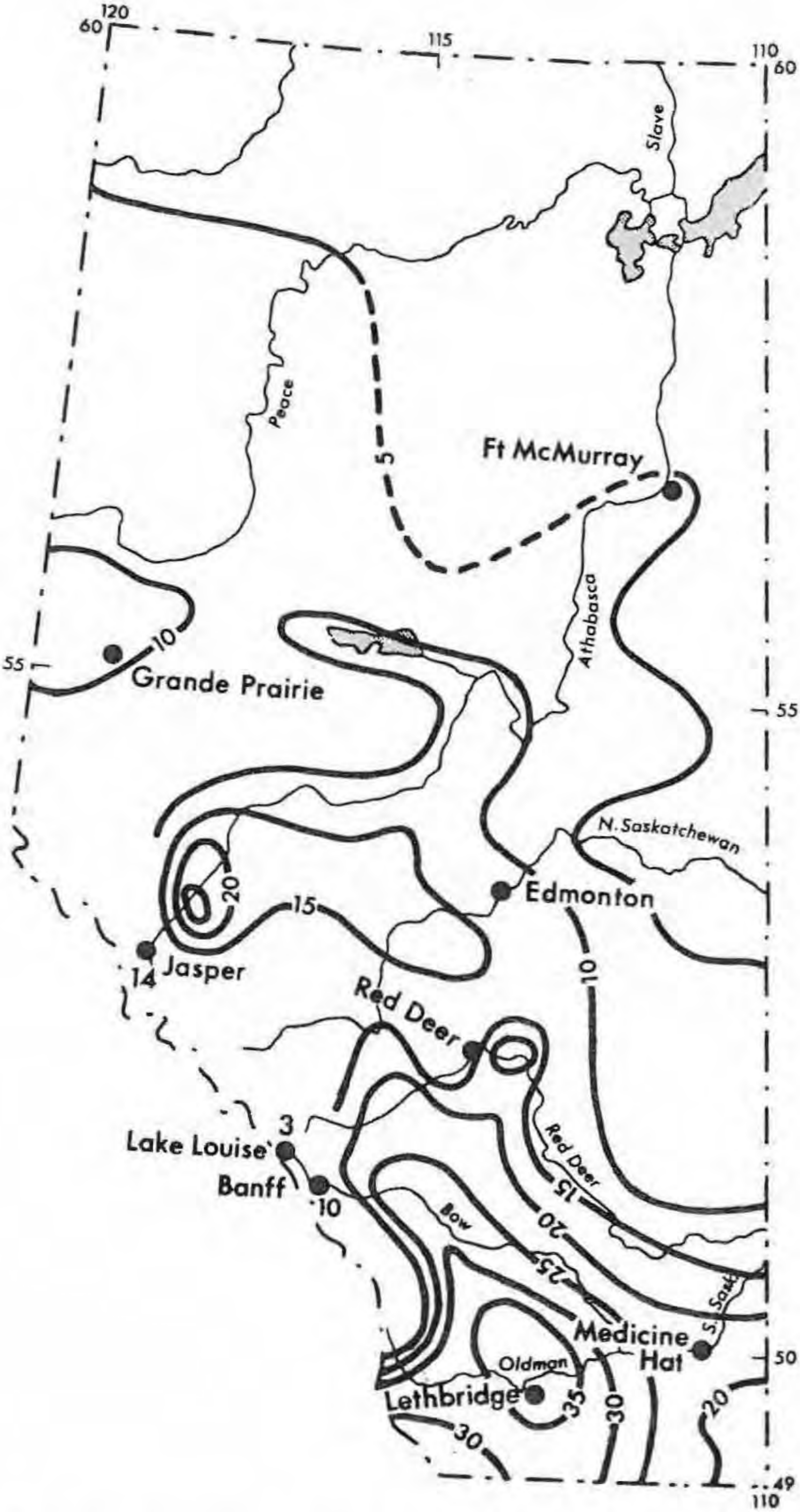


Fig. 1 Mean number of days with chinooks (Max 39°) during the winter (Dec., Jan., Feb.) 1931-65

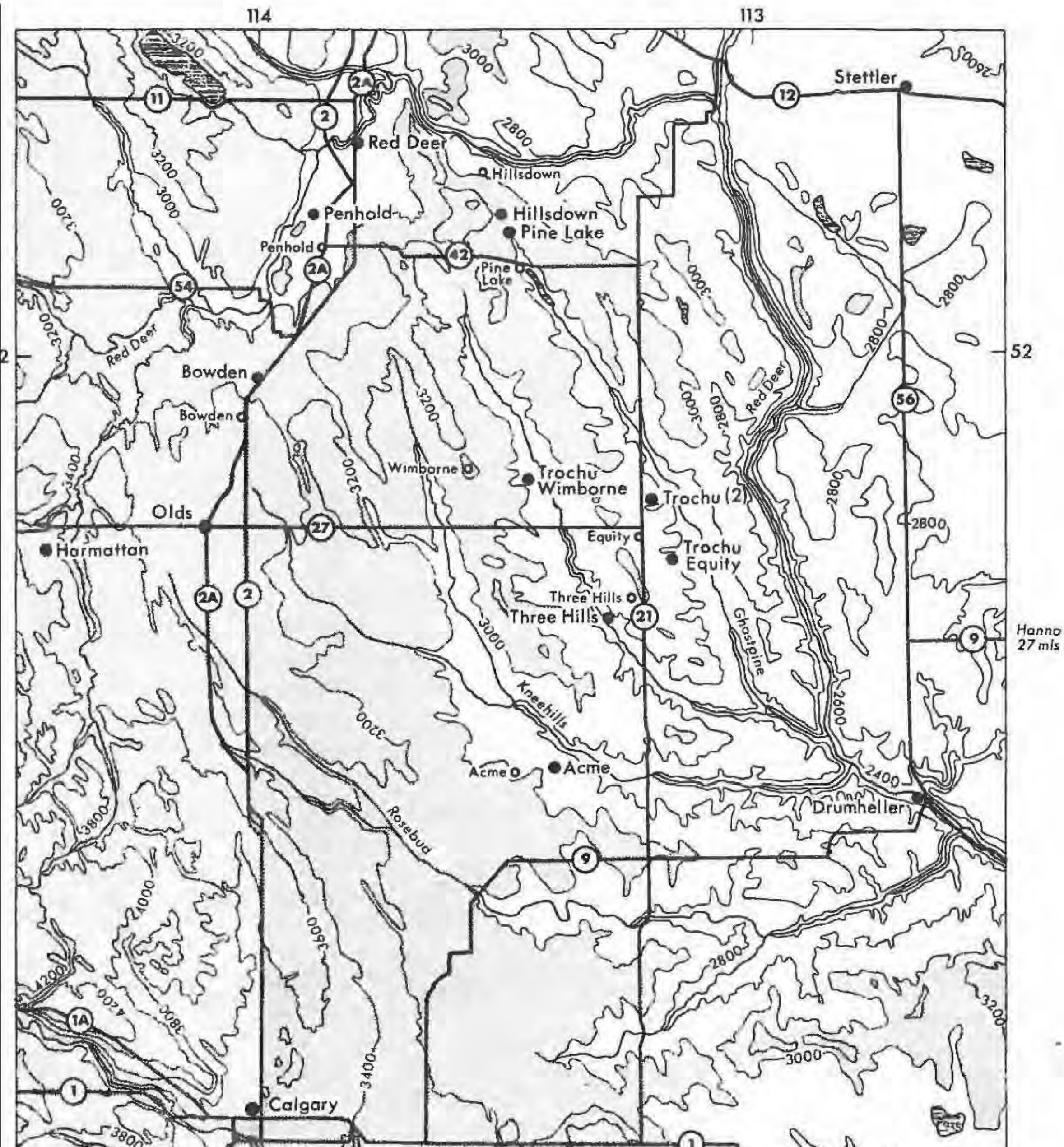


Fig. 2 Topography of the Red Deer-Drumheller-Calgary area

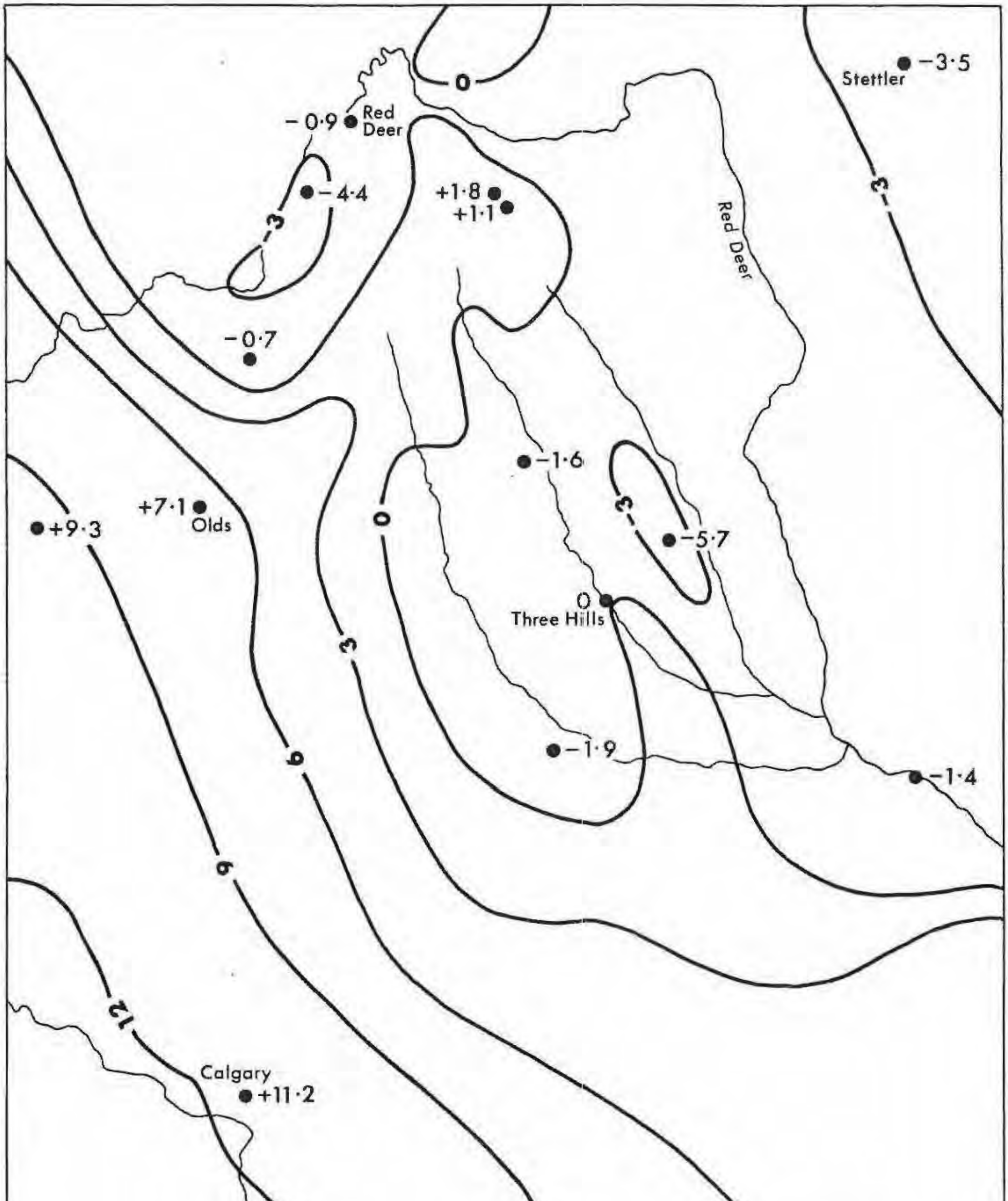


Fig. 3 Number of winter chinook days in the Red Deer-Drumheller-Calgary triangle compared with the number at Three Hills.

FIRST CANADIAN METEOROLOGICAL COMMEMORATIVE POSTAGE STAMP

A five-cent stamp will be issued by the Canada Post Office on the 13th of March 1968 to commemorate the 200th anniversary of Canada's first long-term, fixed-point weather observations.

The weather readings commemorated by this stamp were started at Fort Prince of Wales, Churchill, by William Wales and Joseph Dymond on Sept. 10, 1768; observations several times daily by barometer and thermometer continued until Aug. 27, 1769.

Earlier remarks on the weather had been recorded by soldiers, explorers, and others, but these are largely non-instrumental, and were made in transit, rather than at a fixed point.

Dymond and Wales were at Hudson Bay under instructions from the Royal Society to observe the transit of Venus. Wales, one of the foremost astronomers and mathematicians of his day, was later to accompany Capt. Cook on voyages around the world.

Fort Prince of Wales, a post originally established near the present Fort Churchill, was destroyed by fire while under construction in 1689; it was rebuilt in 1717. The fort is now preserved by the Canadian government as a national historic site.

The new postage stamp is also intended to serve as Canada's recognition of World Meteorological Day, March 23, 1968, which this year is devoted to the theme of Weather and Agriculture.

The weather is acknowledged to have a stronger and more continuous impact on our lives than any other feature of the environment in which we live. Pioneer weather observers led to a vital modern service provided by the Meteorological Branch, Canada Department of Transport, where untold loss of life and property is now-a-days averted by special bulletins ranging from frost warnings for fruit and tobacco growers to hurricane alerts; aviation, industry, public utilities, shipping, agriculture, and forest interests depend on forecast services provided by the meteorologists.

Horizontal in format, the new stamp had dimensions of 40 mm x 24 mm. It is produced by the four-color lithographic printing process in yellow, light blue, indigo blue and ochre. A left panel incorporates an authentic section of a recent weather map prepared by the Meteorological Branch. Yellow and blue are used for the map area; lettering on the top left of the stamp is "Canada"; at the bottom left appears the denomination "5" and "Meteorologie". Wording in this left portion is in indigo on a light blue background. A right panel on the stamp consists of a composite of weather instruments surmounted by "Meteorology"; at the lower right the dates "1768-1968". Lettering on the right panel is printed in white on an indigo background. Indigo and ochre shades are used for the radar antenna and the anemometer superimposed on a principally white weather balloon.

The design selected was executed by the British American Bank Note Company Limited, Ottawa, whose facilities will be used to print the full issue of 24,000,000 stamps.

Normally new stamps remain on sale at local post offices no more than ten days. However, no Canadian stamp is ever invalidated, and the stamp may continue to be purchased from Ottawa for a number of years.

First Day Cover service for the meteorological stamp will be provided by the Postmaster, Ottawa 2, Ontario.

The observations made at the Fort were published in the Philosophical Transactions of the Royal Society in 1771 (Vol. LX for the year 1770). The article is lengthily entitled "Journal of a Voyage Made by Order of the Royal Society, to Churchill River, on the North-west Coast of Hudson Bay; of thirteen Months Residence in that Country; and of the Voyage back to England; in the Years 1768 and 1769; by William Wales".

Attached to the article are the meteorological tables, 42 pages in length, entitled: "Observations on the State of the Air, Winds, Weather, etc., Prince of Wales's Fort on the North-West Coast of Hudsons Bay in the years 1768 and 1769, by Joseph Dymond and William Wales".

The first weather entry is dated Sept. 10, 1768 ("rainy, with a gentle breeze"); the final one, Aug. 27, 1769 ("took down the instruments, and packed them up").

Observations were made under the headings of barometer, thermometer (one inside, one outside), winds, weather etc. Observations were taken three times a day on the average, but there are some days with two, some with three, and the occasional day with as many as five observations.

Most of the observations entered in the Journal are straightforward except that the terminology is more colorful than used today. For example, "a very keen frost air", "the wind high, and much frozen sleet" "the air extremely sharp".

Occasionally the comments range a little further afield: "the liquid in which the plumb-line of the quadrant is immersed, consisting of water, and about one fourth part brandy, is this morning frooze so hard, that I can scarcely make an impression on it with my finger".

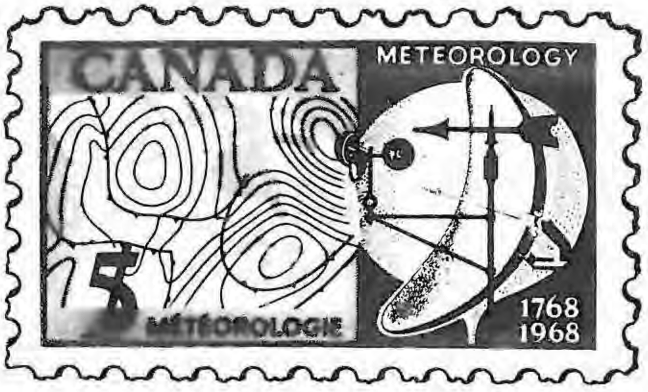
Or this comment on the passage of a cold front (unknown as such of course in those days): "snowing; at this very time, the wind sprung up at northwest on which there was instantly a very sensible change in the heat of the air, so as to be much colder. It had been almost calm all this morning; but about 11 a.m. there arose, almost instantaneously, a perfect hurricane in the northwest quarter, which brought along with it a prodigious quantity of snow, and also a very remarkable change in the temperature of the air".

Or this: "heard a very uncommond sound, seeming to be within the factory; as near as I can liken it, it was the same as firing a small carriage gun; the factory people say it is very frequent in cold weather, and they imagine it to be the beams of the house, as the same is heard on board the ship".

For historical purposes, it should be noted that these first meteorological observations were taken at Fort Prince of Wales, which lies some four miles to the south of Fort Churchill, Manitoba, where weather reports were later taken.

In recent years, the official observing site has been at the airport, located some ten miles from Fort Churchill.

N.B.: It should be noted that the Canadian Weather Service (now Meteorological Branch) dates its founding from the year 1839.



STUDENT'S PRIZE

Members of the Society are asked to keep in mind the new policy regarding a Student's Prize adopted at Congress last spring. Under this new policy, members are asked to propose a student for the prize based on an especially worthwhile contribution, considering the level of education and experience. In this context, a post-baccalaureate "student" is not considered eligible for this prize.

The Prize Committee, to whom recommendations should be made, will be appointed in time to be named in the next issue of ATMOSPHERE.

HOT-WIRE AND SONIC ANEMOMETRY

A DESCRIPTION AND COMPARISON

by
D.M. Whelpdale,
Department of Physics, University of Toronto

The accurate measurement of mean wind velocity and turbulent fluctuations is an important aspect of any field of meteorology, and the area of turbulence measurements is one of the main concerns of micrometeorology. Mean wind velocities can be adequately measured by standard instruments such as cupwheel and vane anemometers, as long as the mean wind remains reasonably steady. Because of the relatively high inertia, and thus slow response time of these mechanical instruments, fluctuations are difficult to measure. Two non-mechanical sensors which are presently in an advanced state of development are quite capable of measuring these turbulent fluctuations - the hot-wire anemometer and the sonic anemometer. Instruments which can detect a range of eddy diameters as well as temperature fluctuations, as both of these instruments can, are immediately adaptable to the measurement of such quantities as vertical fluxes of heat, and turbulence spectra. This paper describes and compares the hot-wire and sonic anemometers and points out some of the applications for which these instruments may be used.

The hot-wire anemometer was one of the first developed for the measurement of turbulent quantities. The detecting element of the hot-wire anemometer is a short, delicate wire, usually of platinum or tungsten, which is heated by an electric current. As a fluid flows past the wire, the wire is cooled and the temperature decreases, resulting in a decrease in the electrical resistance. The wire is cooled by conduction, free and forced convection, and radiation; however, usually only forced convection is important. The amount of heat transferred from the wire depends upon upon the flow velocity of the fluid, the temperature difference between the wire and the fluid, the physical properties of the fluid, and the dimensions and physical properties of the wire. Usually the latter three factors are known, permitting the fourth, the flow velocity, to be found.

The beginnings of hot-wire anemometry, including extensive studies on the cooling of heated cylinders, and the actual construction of a hot-wire anemometer, may be attributed in part to King (1914, 1915). He developed a simple relation between the heat loss, H, of a heated cylinder and the velocity, V, of the fluid which is of the form

$$H = A\sqrt{V} + B$$

where A and B are functions of temperature-dependent quantities, whose values he derived. The heat generated in a wire by an electric current is I^2R where I is the current and R, the resistance; this gives the above relation the form

$$RI^2 = A\sqrt{V} + B.$$

King determined the values of A and B originally and Hinze (1959) gave corrected values; however, these constants are usually found experimentally. It can be seen that this relation gives the possibility of two modes of operation of a hot-wire anemometer. First, the current may be kept constant and the change in resistance of the wire may be used as a measure of the flow of velocity or, second, the resistance or temperature of the wire may be kept constant and the current used as a measure of the flow of velocity. The use of the constant current method has now been developed into a very reliable instrument; however, the constant temperature method has better accuracy and because of recent advances in electronics this method is now preferred.

An example of the latter type of operation is the DISA Constant Temperature Anemometer. In this instrument, the effect of the thermal inertia of the probe is minimized by keeping the sensitive element at a constant temperature. Here, the power required to keep the temperature constant is used as a measure of the wind speed. As well as using a heated wire suspended between two needle supports, a newer modification can also be used: this is a heated thin film on a ceramic backing. (It is far more rugged and may be used readily in liquids.) The hot wire forms one arm of a bridge which is part of a feedback circuit. This instrument provides readings of both the mean flow velocity and the RMS percent turbulence by measuring the DC and AC components respectively of the current required.

The measurable frequency range is from zero to about 60 kHz, depending of course, on the mean flow velocity and the operating temperature. The hot-wire anemometer is extremely important at low air speeds where its sensitivity is highest, and where other instruments, such as cup type anemometers and Pitot tubes, are difficult to use. There is a lower limit of velocity where the free convection from the wire becomes comparable in importance with the forced convection. At the high velocity end of the scale the linear relationship between heat loss and the square root of the velocity does not hold and a correction factor must be applied. The probes used are from 2 to 10 microns in diameter and about 1 millimeter in length; great mechanical strength is required along with an ability to work at high temperatures. Perhaps the best probe to date is a platinum-plated tungsten wire which operates most efficiently at just under 300 degrees C.

The good and bad points of such an instrument should be pointed out. First, some of the disadvantages. Since a hot wire is sensitive to flow from any direction perpendicular to its axis, there will be some ambiguity if there are turbulent components in directions other than that of the mean wind. This fact may be corrected by using a combination of hot wires in the form of an X or V. Even in this case the quadrant of the wind must be known. A second disadvantage is the nature of the hot wire itself: it is extremely delicate and, as such, is prone to be affected by the disposition of impurities, or to be broken by any small bump or vibration. It is used at a high temperature and this will result in changes in calibration. Thus, it must be cleaned and re-calibrated often.

The hot-wire anemometer has many advantages. It is small and therefore affects the medium it is measuring very little (if it is oriented properly to the wind); it is sensitive over a large range of velocities and frequencies; it has a high sensitivity at low wind speeds where standard meteorological instruments do not. It may be used to measure temperature fluctuations and theoretically, density fluctuations.

Two main areas of investigation in which they are used will be mentioned; first, for the measurement of heat and momentum flux in the lower atmosphere; and second for the measurement of the spectra of turbulence near the ground. Swinbank (1951) demonstrated the basic principles of the measurement of the vertical transfer processes by eddies using a combination of hot wire sensors. More recent refinements in this area include the Evapotron of Dyer and Mayer (1965) which uses a refinement of the hot wire called a heated-wake anemometer to measure eddy fluxes in the lower atmosphere. Miyake (1965) has built a wind meter called a constant-temperature-difference-hot-thermocouple-wire anemometer. It also determines the flux of heat and momentum near the surface. In the other area, Biggs (1966) has made spectral measurements of atmospheric turbulence. His instrument detected three components of the wind and used an elaborate automatic data processing arrangement. Elderkin (1966) has also made measurements of the turbulent structure near the ground.

The most recent development in the field of anemometry is the use of the sonic anemometer. Although this instrument was first used in a rather primitive form a little over twenty years ago, recent advances in electronics have made this instrument a powerful research tool. The operation of this instrument includes generating sound waves, transmitting them through a region of the atmosphere, receiving them, and converting them to electronic signals. These signals may then be used as a measure to some parameter related to the time of transit of the sound waves, and thus as a measure of air velocity or temperature.

The theory relating the transit time of the sound waves to the velocity of the wind and the air temperature was developed by Schotland (1955). If the source of sound is small then a sound wave will propagate as a spherical disturbance. If in addition there is instrument is that it is to be a general purpose instrument rather than one for research, limited in scope.

Some of the advantages of the sonic anemometer include the possibility to measure air temperature and wind velocity with the same sensor. The commercial model mentioned above can take continuous measurements of temperature and wind velocity alternately at a rate of two hundred per second. The instrument has a linear response to wind and temperature and has rapid response because there is no inertia of moving parts. Because of its size and method of measurement, it can take spatial averages of other types of anemometers. The sonic thermometer is particularly valuable because it gives an absolute measurement of temperature with almost no susceptibility to radiational errors. Solid state electronics can be easily used with the sonic anemometer and this means low power requirements; this could prove useful for use in remote stations.

Although there are many advantages to the sonic instruments, there are also some disadvantages. The wind velocity component measured is a line average over the sound path. Thus, fluctuations corresponding to eddy diameters shorter than the path length of the sound will be averaged out. This is a basic limitation on the limit of high frequency measurements due to the geometry of the system. Another limiting factor is the cost and complexeity of the electronics involved. In the actual operation of the instrument, errors can be introduced from fluctuations in the temperature field if the two paths of the sound are not identical. In a study of turbulent motions the size of the transmitters and receivers must be carefully considered. They should, of course, be as small as possible; also it should be taken into account that the parts themselves will introduce turbulence into the measuring region.

As the hot-wire anemometer, the sonic anemometer or sonic anemometer-thermometer has found many uses. Alekseev (1965) describes the use of an acoustic micro-anemometer for measurements of turbulent fluctuations of temperature and velocity of wind in the ground layer of the atmosphere. Kaimal and Businger (1963) used their continuous wave sonic and wind fluctuations. These fluctuations allow computation of the eddy heat flux. The same type of instrument was used by Kaimal and Izumi (1965) for measurement of vertical velocity fluctuations in a nocturnal low-level jet. By varying the base line of a sonic anemometer a desired scale of turbulent fluctuations could be measured, since any smaller in diameter than the base line would be averaged out.

As may be seen from the above discussion both the hot-wire anemometer and the sonic anemometer are widely used in research and have many applications. The preference for one instrument over the other is more a matter of the application it is to be used for, rather than the overall superiority of one instrument. The sizes of the two motion of the atmosphere, that is, wind, then the motion of the sound wave relative to a stationary point will be given by the vector sum of the sound and wind velocities. If one considers the simple case of measurement in the direction of the wind, then the transit time or phase difference of the sound wave over the distance can be measured. Or if two sound disturbances are made to travel the same distance simultaneously in opposite directions, the difference of transit times or difference of phases may be found. Usually this latter method is used. A relationship between the time difference, Δt, and velocity (or mass transport) is developed by Suomi in Lettau and Davidson (1953):

$$\Delta t = 2d\rho V_d / \gamma p = \text{constant } (\rho V_d),$$

where d is the distance travelled; ρ, the air density; V_d, the line average component of wind parallel to the direction of measurement; γ, the ratio of the specific heats of air, c_p/c_v; and p, the atmospheric pressure. This equation demonstrates a most important asset of the sonic anemometer: a linear relation between the transit time difference and velocity.

Many variations of the sonic anemometer have been developed. The original instrument was that of Carrier and Carlson (1944) who used the phase difference between signals received from one upwind receiver and one downwind receiver from the sound source, to measure wind velocity. Another type was that of Corby (1950) who used a sound source in the centre of four receivers placed at 90 degrees to each other. These elements were placed on large pillars and undoubtedly the wind flow was affected by the pillars. Bovsheverov and Voronov (1960) used a setup similar to Corby's but on a much reducded scale; their instrument was only inches high. It operated at 20 kHz and used a phase comparison method. Methods such as these are susceptible to erros introduced by temperature fluctuations along the different paths the sound takes.

The more usual arrangement of transmitters and receivers now is to have two systems of transmitter-receiver side by side, in opposition with paths crossing. One of the first instruments of this type was developed by Suomi and Barrett (1949) and modified by Suomi as described in Lettau and Davidson (1953). Short bursts of 80 kHz sound are used and pulses coming from one transmitter are slightly delayed to avoid the ambiguity of determining which arrives first when measuring the time difference. An instrument of this type was used in the O'Neill program. Kaimal and Businger (1963) developed a similar instrument; however, they used continuous sound waves instead of pulses because such as system is more stable and less noisy, and they used phase angle variations for determining both temperature and vertical wind variations simultaneously. Probably the most recent instrument is that described by Mitsuta (1966). It is a sonic anemometer-thermometer which is to be produced commercially by the Kaijo Denki Company of Japan. This instrument also uses the pulse time-difference method with a slight delay. The biggest advantage of this instruments lead to differences. The sensing element of the hot-wire anemometer is very small and thus a measurement with it could be termed an Eulerian point measurement; this is obviously not the case with sonic anemometer. However, where the hot-wire anemometer can take only point measurements and time averages, the sonic anemometer is capable of spatial averages, with the possibility of using very long base lines for averages over a distance such as an airfield. The smallest base line of the sonic anemometer imposes a lower limit on the sizes of eddies which can be measured. One very important factor in the use of the sonic anemometer is that the sound and receiving heads can cause the formation of turbulence along the measuring path. At a large enough velocity this will affect the field of measurement.

Another important difference between the two is that whereas the hot-wire anemometer must be calibration with another instrument, such as a Pitot tube, the sonic anemometer is an absolute instrument in that it depends only on well known physical constants.

When actually using these instruments there are definite advantages to be obtained with the sonic anemometer. The hot-wire anemometer, as noted earlier, must be cleaned and re-calibrated regularly and the wire may be damaged easily. It is incapable of functioning in rain. The sonic anemometer is more rugged and stable and can be used in adverse weather conditions, such as storms. For these reasons the sonic anemometer is a better field instrument, and the hot-wire anemometer is more suited to laboratory work than unattended field operation. One last comment on the operation of the sonic anemometer-thermometer is that it can measure both temperature and wind velocity using the same sensors. The alternate measurements of the two quantities can be made with a high frequency.

In conclusion, it appears that both instruments have decided advantages over previous anemometers such as the cupwheel or vane types. However, choosing the superiority of one over the other is not a reasonable decision to make because each excel at certain different tasks. Thus, the application for which the instrument is to be used, and at present, cost considerations, will undoubtedly be the criteria on which the choice between the two is to be based.

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INTER ALIA

Conference on Agricultural Meteorology
May 21-23, 1968, Ottawa, Canada

The Eighth National Conference on Agricultural Meteorology of the American Meteorological Society will be held in Southam Hall at Carleton University, Ottawa, Ontario, Canada, May 21-23, 1968.

Sessions on several aspects of Agricultural and Forest Meteorology will be developed from invited papers, panel discussions and volunteer contributions. The program will include such topics as weather information applied to decision-making, micrometeorological studies of crops and forests, interactions between organisms and their environment, photosynthesis and water-use efficiency and environmental manipulation and control. Contributions on these and other topics are invited. A special session on the International Biological Programme is being arranged. Post-conference field trips are being planned to the IBP and micrometeorological studies at the Forest Experiment Station, Petawawa and the University of Guelph.

Information on accommodation, field trips and the ladies' program may be obtained from Mr. Geo. W. Robertson, Agrometeorology Section, Plant Research Institute, Canada Department of Agriculture, Ottawa 3, Ontario.

Send titles and abstracts to the Program Chairman, Dr. K.M. King, Dept. of Soil Science, Univ. of Guelph, Guelph, Ontario, Canada, before 1 December, 1967.

INTERNATIONAL CONFERENCE ON CLOUD PHYSICS

TORONTO, AUGUST 26-30, 1968

An International Conference on Cloud Physics will be held at the University of Toronto from August 26-30, 1968, under the joint sponsorship of the International Association of Meteorology and Atmospheric Physics of the International Union of Geodesy and Geophysics, the World Meteorological Organization, the American Meteorological Society, the Canadian Meteorological Society, and the National Research Council of Canada.

The Conference has the following goals: (a) presentation and discussion of new achievements and their implications; (b) survey of the different domains of cloud physics; (c) stimulation of the training of physics students in cloud physics by promoting appropriate laboratory experiments for undergraduate physics courses.

The program will consist of the following ten sessions:

1. Weather active condensation nuclei.
2. Liquid cloud particles.
3. Ice nuclei and nucleation.
4. Ice and snow crystals.
5. Formation of rain.
6. Formation of hail.
7. Cloud dynamics.
8. Electrification of clouds and precipitation.
9. Weather modification.
10. Experiments in cloud physics for physics students.

The authors are asked to submit the titles and abstracts by February 15, 1968, and the manuscripts by March 31, 1968, so that the proceedings can be mailed six weeks before the Conference starts. Detailed instructions about the preparation of camera-ready manuscripts will be mailed in October/November, 1967, or later by the Organizing Committee if requested. Since about 150 papers are expected a personal oral presentation will not be possible; however, "lead speakers" will summarize groups of papers. By means of such a procedure ample time for discussion will be available.

A few invited speakers will present survey papers on diverse, contemporary aspects of cloud physics.

Those who plan to attend and wish to obtain the Circulars containing further information should contact the Chairman of the Organizing Committee: Professor R. List, Department of Physics, University of Toronto, Toronto 5, Ontario, Canada, at their earliest convenience.

13127 124 Avenue,
Edmonton, Alberta.

March 30, 1967.

Editor,
"ATMOSPHERE",
The Canadian Meteorological Society,
315 Bloor St. W.,
Toronto 5, Ont.

Sir:

In the Vol. 4 #3 (Fall 1966) issue of ATMOSPHERE, Mr. J.G. Potter queries "The Highest Temperature in Canada"? His discussion appears valid that the 115° at Gleichen and the 114° at Lundbreck must have been in error.

There are probably many mistakes in our climatological records. At the Edmonton Weather Office we wonder about the highest February temperature, 76°, given for Calgary, which is supposed to have occurred on 23 February 1908.

This is far above the highest February temperatures at other places in Alberta. For example

Lethbridge	67	on February 12, 1934
Edmonton	62	on February 27, 1889
Medicine Hat	65	on February 8, 1954

The next highest temperature at Calgary is 66, a record which was set February 18, 1916, and equalled February 12, 1934.

Connor (1920) gives these as the extreme high temperatures for February in the three decades 1885 to 1914:

	1885 - 1894	1895 - 1904	1905 - 1914
Calgary	57	59	76
Medicine Hat	61	60	64
Edmonton	62	56	54
Didsbury	---	---	66
Gleichen	---	---	58
Hillsdown	---	---	59
Alix	---	---	57
Lethbridge	---	---	65
Macleod	---	61	62
Banff	---	47	49
Ranfurly	---	---	49

For February 23, the highest temperatures at some places in Alberta, according to the figures we have in the forecast office, are Lethbridge 59 in 1907; Edmonton 52 in 1921; and Medicine Hat 60 in 1954.

It would appear that the highest February temperature for Calgary might be somewhat lower than the 76° currently in the record book.

REFERENCE

Connor, A.J. 1920 The Temperature and Precipitation of Alberta Saskatchewan and Manitoba. Meteorological Service of Canada.

R.G. Stark.

COMMENTS ON ARTICLE BY STARK

The extreme high temperature of 76° for Calgary for February noted by Mr. Stark had previously been brought to the attention of the Climatology Division by Mr. C.W. Drew, Jr. of Calgary. In checking this value Mr. S.R. Anderson of the Climatology Division used a method of analysis of extreme values as described by Kendall and concluded that the 76° was in error, as the analysis indicated any value greater than 66° would be very improbable.

Since the purpose in publishing the article on the extreme high temperature for Canada was not only to correct this one value, but also to encourage a critical examination of other extreme values retained in our records, the response of Mr. Stark and others has proved very gratifying. As a result some of these improbable values will not be carried in future publications such as "Climatic Tables" for each province and "Climatic Normals Vol I - Temperature Normals and Extremes" which are scheduled for publication in the summer of 1967.

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J.G. Potter

LA SOCIETE DE METEOROLOGIE DE QUEBEC

par G.-Oscar Villeneuve

La Société de Météorologie de Québec a été fondée officiellement le 14 octobre 1964 lors d'une deuxième assemblée générale des personnes intéressées directement ou indirectement à la météorologie et à ses applications. La première réunion avait eu lieu en mai et groupait une vingtaine de personnes. Cette réunion de fondation du 14 octobre rassemblait plus de 30 membres éventuels qui sont par profession météorologistes, agronomes, forestiers, biologistes, chimistes, ingénieurs, géologues ou géographes. On a procédé à la lecture et à l'acceptation d'une constitution et de règlements et à la nomination d'un conseil d'administration.

Voici depuis sa fondation, les dates de réunion de la Société, le nom du conférencier-invité et le sujet traité:

Date	Nom	Sujet
11 nov. 1964	Jacques Bureau, tech., Technicien en météorologie Prévisionniste à la télévision de Québec.	Les prévisions météororologiques
9 déc. 1964	Jean-Victor Arpin, Ing., Directeur de la Voie Publique pour la Cité de Montréal.	Le déneigement à Montréal
16 fév. 1965	S.-J. Bourget, Ph.D., Professeur, Faculté d'Agriculture de Laval, Québec, P.Q.	La pluie est-elle toujours bienfaisante?

23 mars 1965	P.-E. Vézina, D.Sc., Professeur Faculté de Foresterie et de Géodésie de Laval, Québec, P.Q.	Le rôle de la forêt dans la formation du climat local
20 oct. 1965	André Robert, D.Sc., Centre d'analyse, Service Météorologique du Canada, Dorval, P.Q.	Utilisation des ordinateurs en recherches météorologiques
17 nov. 1965	Michel Slivitzky, Ing., Directeur des Eaux, Ministère des Richesses naturelles, Québec, P.Q.	Application de la météorologie aux problèmes du génie
15 déc. 1965	G.-Oscar Villeneuve, Ph.D., Directeur, Service de Météorologie, Ministère des Richesses naturelles, Québeç, P.Q.	Les applications de la météorologie en France
16 fév. 1966	Bernard Michel, D.Sc., Professeur, Faculté des Sciences de Laval, Québec, P.Q.	De la nucléation des cristaux de neige dans les nuages à la formation du frasil dans les rivières
16 mars 1966	C.C. Boughner, M.Sc., Chef, Division de la Climatologie, Service Météorologique du Canada, Toronto, Ontario.	L'Organisation météorologique mondiale et le Service Météorologique du Canada
19 oct. 1966	Raymond Gagnon, M.Sc., Météorologiste, Service de Météorologie, Ministère des Richesses naturelles, Québec, P.Q.	Le climat du Grand-Nord québécois
16 nov. 1966	Raymond Pelletier, Ing., Service de la Voie Publique, Cité de Québec, P.Q.	Effets du gel sur les chaussées et les moyens de prévenir ses effets
14 déc. 1966	Benoît Robitaille, D.L., Géographe, Direction du Nouveau-Québec, Ministère des Richesses naturelles, Québec, P.Q.	Des glaces dans l'Est de l'Arctique canadien

15 fév. 1967	Elzéar Campagna, D.Sc., Professeur, Faculté d'Agriculture de Laval, Québec, P.Q.	Les recherches à la station LES BUISSONS sur la Côte Nord du St-Laurent
15 mars 1967	Bernard Philogène, M.Sc., Scientifique, Laboratoire de Biologie forestière du Canada, Québec, P.Q.	Les facteurs climatiques dans le phénomène de la diapause chez les insectes

En avril 1965 et 1966, il y eut également assemblée générale des membres pour entendre les rapports du président et du secrétaire-trésorier et pour la tenue des élections annuelles au conseil d'administration. On sait que le budget de la société est constitué d'une cotisation annuelle au montant de $2.00 de chacun des membres. En 1966-1967, la Société a reçu un octroi de $50.00 d'une firme commerciale et a pu de cette façon continuer ses "opérations financières" sans difficultés.

Les réunions ont eu lieu jusqu'à date soit à l'amphithéâtre de l'Aquarium du Pont de Québec, soit au Centre Audio-visuel de la C.E.C.Q., rue Bourlamaque, Québec.

Le présent conseil d'administration comprend les membres suivants:

Président: G.-Oscar Villeneuve

Vice-président: L.-J. O'Grady

Sec.-trésorier: Michel Ferland

Conseillers: Cynthia Wilson
Raymond Pelletier
Rénald Naud
Antoine Hone
Jules Dionne.

L'assemblée générale de la présente année aura lieu en avril. A cette occasion, on procédera comme chaque année à l'élection d'un nouveau conseil d'administration. Il sera également question de créer un Chapître de Québec de la Société de Météorologie du Canada.

EMERGING PROBLEMS IN THE MANAGEMENT OF ATMOSPHERIC RESOURCES IN CANADA

W.R. Derrick Sewell and J. Elizabeth McMeiken

The atmosphere is one of the most valuable assets available to man, for without the winds, precipitation and temperature which it provides, all life would cease to function. So plentiful have they been that man has tended to take them for granted. They have in fact been regarded as free goods, available to anyone to do what they like with them, where and when they choose to do so. It seems, however, that we are now rapidly approaching the stage where the atmosphere must be recognized as an economic resource, and its use managed and controlled as are other resources.

A number of recent developments have emphasized the need for a completely new and comprehensive approach. First, the use of the atmosphere as a means of waste disposal has become a matter of considerable concern in many parts of Canada. Millions of dollars are expended each year in efforts to abate atmospheric pollution. Problems are especially severe in certain industrial and urban areas of the country. Chronic bronchitis, resulting in part from air pollution, costs Canada a loss of at least 650,000 working days every year.[1/] Property losses in Canada due to pollution damage are increasing considerably with the upsurge of industrialization and urbanization, with prospects of much greater losses in the next few years.

A second factor has been the mounting toll of losses due to severe weather events. Each year floods, hailstorms, lightning, tornadoes, snowstorms, fogs and droughts result in huge losses of property and income. There are no precise figures on these losses, but compensated losses alone amount to well over $5 million a year. Actual losses are of course much more than this. Compensation for losses resulting from the Winnipeg Flood in 1950, for example, exceeded $16 million.[2/] Actual losses, however, may have been as much as $100 million. Droughts in the Prairies have also caused huge losses. In 1960 over $4.5 million was paid out in compensation for such losses. During the summer of 1967 fighting of forest fires in British Columbia cost the provincial government over $6 million. Many of these fires were started by lightning. Even "normal" weather can be costly. The winter in Manitoba is said to cost the average Winnipeger over $1,000 a year in expenses, which can be directly attributed to snow and ice.

Thirdly, man's increasing ability to modify the weather has brought a new awareness to the resources of the atmosphere. After years of considerable skepticism there now appears to be a growing agreement among meteorologists that it is possible under certain circumstances to change normal weather patterns. Motivated by a desire to overcome weather-related problems, and encouraged by the reports of two major scientific committees that weather changes are feasible,3/ the United States government has embarked upon the development of major modification programmes. It is expected that by 1970 the United States government will be spending over $50 million a year on research and development in this field.4/

It is inevitable that the expansion of weather modification in the United States will have profound effects in Canada. First, it is likely that it will stimulate further activity in this connection in Canada. Weather modification has already taken place in many parts of the country. Hydro-electric power companies in Quebec and British Columbia have hired commercial cloud seeding companies to induce precipitation to raise water levels in their reservoirs.5/ Farmers in several provinces have engaged such companies to induce precipitation in periods of prolonged drought. They have also hired them to suppress hail. Forest companies in Ontario and Quebec have engaged in weather modification activities too, attempting to snuff out forest fires. Armed with the conclusions of the two scientific committees that weather modification can be accomplished, commercial cloud seeders are likely to be able to expand the market for their services in many parts of Canada.

The expansion of weather modification activity in the United States is likely to have a second set of effects on Canada. Because of the dynamic nature of the atmosphere, it is possible that there may be spillover effects of United States' weather modification programmes (in the United States). These spillover effects may or may not be beneficial. If they are adverse, there is nothing that Canadians can do to obtain compensation. The new era of weather modification will require, therefore, innovations in international law and institutions to handle such problems.

Present Policies.

At present public policies relating to the management and use of atmospheric resources in Canada are limited to the provision of information about the probable state of the atmosphere, the control of air space, and to a minor extent, the control of air pollution. The Meteorological Branch of the Department of Transport is the principal federal government agency involved in this work and also operates in conjunction with various other federal and provincial agencies. Their principal contribution has been the gathering, analysis and publishing of weather data. Moreover, some agencies issue storm and flood warnings.

Air space has been under the direct control of the Department of Transport using standards set by the International Civil Aviation Organization. The Department of National Health and Welfare is the principal provider of funds for the collection of information and research efforts in the field of air pollution. The control of air pollution, however, is becoming a matter of increasing concern to provincial governments, and most of them have now enacted limited air pollution regulations. Several of them have established Pollution Control Boards. Despite this progress, however, with no organized programme at the provincial level to deal with overall atmospheric matters and with the limited responsibility assumed by the federal government, it appears that much remains to be done. Further changes in policies, laws, and administrative structures will be needed to cope with the problems that the management of atmospheric resources will pose in the next few years.

At present there is no control over weather modification activities in Canada. Thus far the absence of such control has presented no problem. But as the magnitude of weather modification activity grows, conflicts are bound to arise. Controls of various kinds will therefore be required. First, commercial weather modification firms will want protection against other firms or agencies in their operations. Second, clients will need assurance as to the qualifications and integrity of the personnel of such firms. Third, researchers will also need assurance that their experiments with clouds will not be hampered by the operations of other cloud seeding firms. Fourthly, the public at large will need to be assured that such activities are in the public interests, and that means are available for registering opposition to weather modification and for obtaining compensation for losses.6/

Future Policies.

Problems created by increasing air pollution, severe weather events and man's expanding ability to modify the weather pose two major challenges for public policy in the resources field. The first relates to the ownership of atmospheric resources and the second is concerned with how far the government should get involved in managing such resources.

While the B.N.A. Act is fairly specific about the ownership of most resources, it is unclear about such aspects as offshore minerals or atmospheric resources. Thus far there has been no need to determine whether the federal government or the provincial government has jurisdiction over them. There has been no demand for offshore minerals and there have been no conflicts in the use of atmospheric resources. A point has now been reached, however, in the case of offshore minerals where a decision as to ownership has been demanded. A contest between B.C. and the federal government has recently been before the Supreme Court of Canada.7/

Whether the matter of jurisdiction over atmospheric resources should be decided in a similar fashion, however, is open to debate.

Whatever level of government is granted jurisdiction over atmospheric resources, government involvement in their management is bound to increase. Governments will be called upon to provide more information not only about what the weather is likely to be but also what impacts weather variations are likely to have. Without information on weather effects it is impossible to decide which of the several possible adjustments to the weather is the most efficient. For example, farmers might adjust to a potential drought condition by rescheduling their operations, developing drought-resistant crops, or by trying to modify the weather. In a given instance the latter might appear the most efficient from the farmer's point of view but it might also result in losses to other activities. To determine which adjustment was in the public interest, governments would need to have much more information on the effects of weather variations on different activities than is presently available.

Weather information programs in Canada are not only small but they are fairly narrowly focussed. Most of the $22 million that is spent on such programs is devoted to the provision of data for weather forecasting. Little or no information is collected on weather impacts nor about the way in which people use weather information. Consequently, there is not at present any measure of the value of weather information programs in Canada, nor any indication of the value of expanding them. The collection of data on weather impacts and uses of information should therefore be given high priority in future policies relating to the management of atmospheric resources.

Similar comments could be made about the present level of atmospheric research in Canada. Today less than $5 million a year is spent on such work. Fewer than 100 scientists are engaged in studies in this field.[8/] Although the possibilities of expanded weather modification are very real, little money is devoted to research on that subject. No funds at all are devoted to examinations of weather impacts. It should be clear from the foregoing discussion that a much larger research effort will be necessary if the problems that are now on the horizon are going to be met effectively. It should also be evident that studies on the economic, social and political dimensions of the management of atmospheric resources are urgently required.

Besides expanding their efforts in data collection and research governments will be called upon to exercise increasing control over the use and modification of the atmosphere. Decisions will have to be made as to what types of regulation are needed, which level of government should administer them, and how they should be enforced. Moreover it will have to be decided whether governments will be active participants or merely managers, particularly in the case of weather modification projects. These are questions which should be occupying the attention of those government agencies that have responsibilities in the management of natural resources. They present a rare opportunity in the resources field, the opportunity to plan for future action rather than to react to the crisis.

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