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TECHNICAL REPORT
EP-38

TOPOCLIMATIC STUDY, FORT CHURCHILL, CANADA

QUARTERMASTER RESEARCH & DEVELOPMENT CENTER
ENVIRONMENTAL PROTECTION RESEARCH DIVISION

APRIL 1956

NATICK, MASSACHUSETTS

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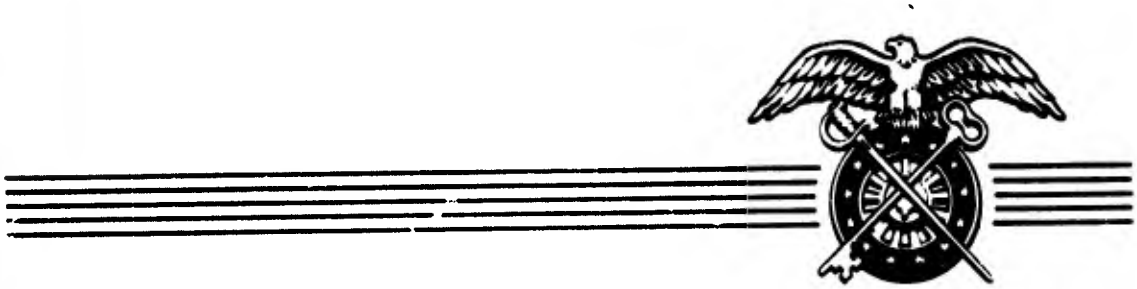

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Natick, Massachusetts

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Technical Report
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A TOPOCLIMATIC STUDY, FORT CHURCHILL, CANADA

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REGIONAL ENVIRONMENTS RESEARCH BRANCH

Project Reference:
7-38-03-008B

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Foreword

Persons engaged in field-testing items of equipment and clothing at Fort Churchill have observed marked differences between temperatures and wind speeds at their site of operations and those recorded at the Canadian Meteorological Station at the airfield. In order to determine the nature of these differences, especially with respect to local effects of relief and vegetation, a study was made during a 23-day period in January and February 1955. The results of this study are a contribution to the understanding of variations in local climate at Fort Churchill, and should aid in the selection of sites for cold-weather tests.

This study, the first such undertaken by this Command, served as a prototype for other, more comprehensive microclimatological investigations which are now in progress at Big Delta, Alaska, and at tropical and desert test sites.

Austin Henschel, Ph.D.
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Contents

Abstract

A topoclimatic study was conducted during a 23-day period from 16 January through 7 February 1955, to obtain information concerning local variation of winter temperatures and wind speeds in the vicinity of Fort Churchill, Canada. Temperature and wind speed at five field stations and at the Canadian Meteorological Station at the main camp were noted and compared.

Results of the study indicate that lowest temperatures may be expected in low, snow-covered areas having little or no vegetation. The warmest areas are those that are heavily wooded; vegetation reduces loss of heat and lowers wind speeds by its frictional effect. During the observation period, strongest and most consistent winds were recorded on a ridge overlooking Hudson Bay, and at the main camp where the anemometer was about 70 feet above the ground. Lowest wind speeds and the greatest frequency of calms occurred in the woods. Low temperatures occurred more frequently with light to moderate winds than with calm conditions.

For the period of study, there was no correlation between hours of sunshine and diurnal temperature range, or between hours of sunshine and diurnal wind variation.

A TOPOCLIMATIC STUDY AT FORT CHURCHILL, CANADA

1. Introduction

Fort Churchill, Canada, is in the province of Manitoba on the western shore of Hudson Bay, at latitude 58° 47' N. and longitude 94° 05' W. (Fig. 1). The military camp, situated close to the town of Churchill, is used for winter testing by various technical services of the United States Army.

The climate of Fort Churchill is similar in many respects to that of cold continental interiors, but because of the influence of Hudson Bay, temperature extremes are not as great as those of most interior regions.

Low temperatures, the major consideration for Arctic and subarctic testing, prevail throughout the long winter period. Temperatures at or below 0°F may be expected on 20 days in December, 30 in January, and 27 and 26 days respectively during February and March. Temperatures at or below -25°F occur from December through March; January and February have about 18 and 17 days respectively with such temperatures. The absolute minimum temperature recorded at Fort Churchill, -57°F, occurred in both January and February, in different years.

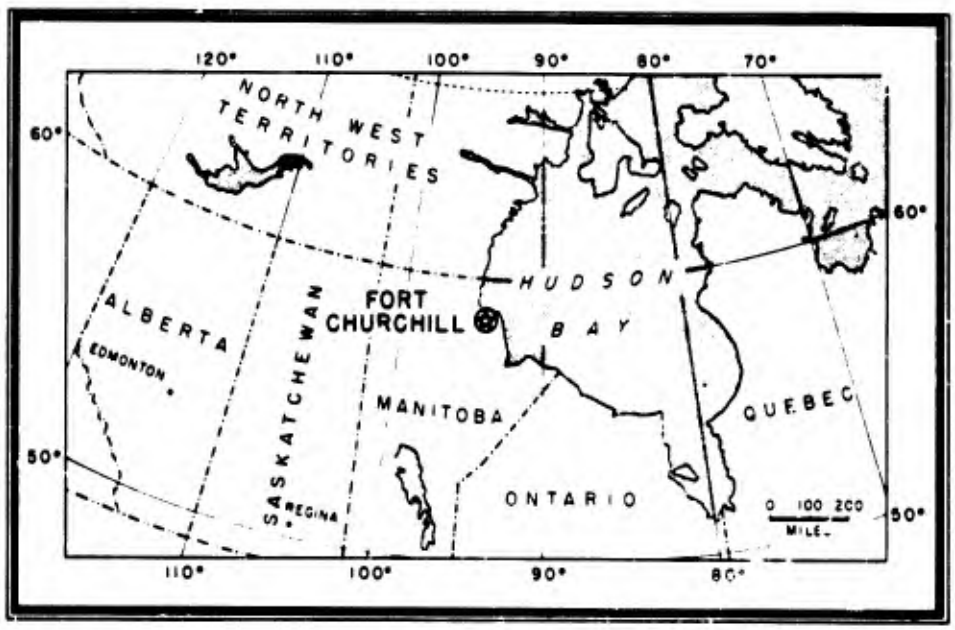

Figure 1: Location of Fort Churchill

In addition to low temperatures, wind must be considered in tests related to determining the proper functioning of clothing and equipment. This is especially true in Arctic and subarctic regions where windchill (the cooling effect of wind at a low temperature) plays a critical role in determining the suitability of clothing and in affecting physiological reactions of troops serving as test subjects. Fort Churchill is known for its high wind speeds which persist throughout the year. From November through March the average monthly wind speed is over 14 mph. During these months, winds of 13 to 38 mph may be expected about 50 percent of the time or more.

The Fort Churchill area is flat and water-logged, generally less than 25 feet in elevation. Exceptions to this are ridges of hard, crystalline rock, and a few scattered gravel ridges which rise to 100 feet and upon which the major portion of the military installation is located. The ground is frozen and snow-covered from late September or early October until April or May.

The area is in the transition zone between the subarctic boreal forest and the Arctic tundra, and the vegetation shows pronounced evidence of the severe environment. There are no trees on the more exposed positions. Owing to the swampy conditions generally associated with a high permafrost table, plants well adapted to moist or wet ground tend to dominate. Two major vegetation types may be distinguished: (1) northern coniferous forest, and (2) tundra, which includes lichenous high tundra on ridges, and muskeg in lower areas.

2. Purpose

The purpose of this study was:

a. To determine the degree to which temperature and wind speeds differ at field locations having different vegetation and topographic features, and the difference between these field stations and the Canadian Meteorological Station at the main camp.

b. To support, where necessary and possible, the test activities of other elements of the Quartermaster Corps, by providing meteorological and climatic data during periods of testing.

c. To serve as a prototype, particularly with regard to selection of sites, instrumentation, and procedures, for topoclimatic studies to be conducted in the future at other Department of the Army test sites in the Arctic and subarctic areas.

3. Location of Observing Stations

Four weather-observing sites were selected, based on the following considerations: (1) the greatest differences in temperature and wind

could be expected, (2) they were representative of different types of terrain and vegetation, and (3) personnel of the Quartermaster Corps and other Technical Services were conducting tests there. Stations were placed (with the exception of the Forest Station) 60 to 100 yards from heated buildings which were used to house the electrical recording elements of the instruments.

Data from these stations were supplemented by temperature and wind data from the Canadian Meteorological Station at the airfield, and by temperature data from the Corps of Engineers test area at South Camp. Locations of stations are shown on Figure 2.

a. Farnworth Lake

A station was established on the ice at Farnworth Lake, 4.4 miles (by road) from the main camp. The station was about 75 yards south of the headquarters building of the Quartermaster Field Evaluation Agency test team, and 35 yards out on the ice of the lake (Figs. 3 and 4). The surface of the lake was frozen and covered with 8 to 12 inches of snow. This station was far enough from buildings or vegetation so that measurements were not influenced by them.

b. Quartermaster, South Camp Station

A second station, designated "QM, South Camp", was installed in the South Camp area approximately 2 miles from the main camp (Figs. 5 and 6). This area is used by the Corps of Engineers for testing equipment. The station was in a shallow depression about 60 yards from the headquarters building of the Corps of Engineers. There was no surrounding vegetation, and cold air drainage into this area could be anticipated under calm conditions.

Because of the depth of the snow (1 to 2 feet) the instrument shelter was placed on a wooden platform on top of the snow cover to provide stability for the shelter and to maintain the proper height of recording instruments (Fig. 6). The recorders were located in the heated headquarters building of the Corps of Engineers.

c. Corps of Engineers, South Camp Station

This station, established and operated by the Corps of Engineers, was called "ENG, South Camp". It was approximately 100 yards from the QM, South Camp Station. The temperature-sensing element (thermocouple) was located at the top of a 2-foot pole on the roof of an unheated part of a building. The thermocouple was about 15 feet above the ground, 35 to 40 feet higher than the thermograph in the instrument shelter of the QM, South Camp Station. It was shielded from direct radiation

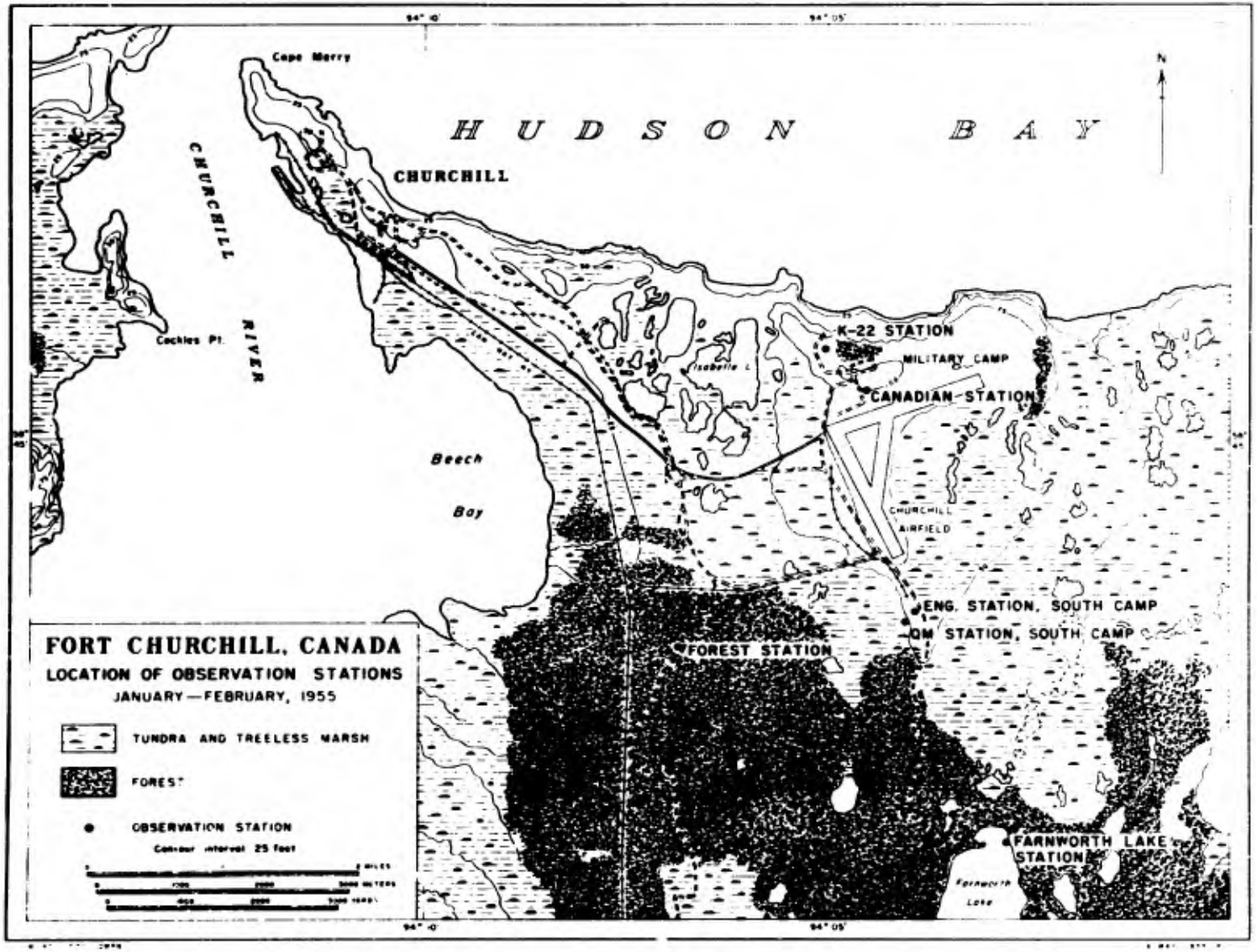

Figure 2. Location of Observing Stations

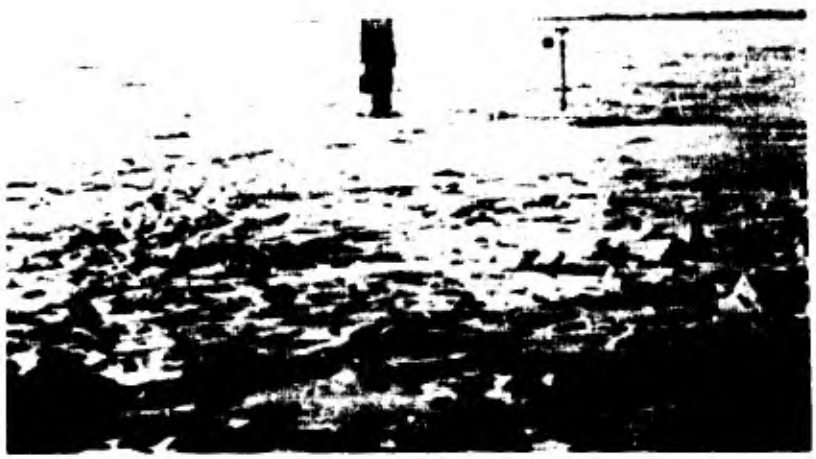

Figure 3. Farnworth Lake Station. View looking south.

Figure 4. Farnworth Lake Station. View looking east toward QM Field Evaluation Agency test area.

Figure 5. QM, South Camp Station. View looking south.

Figure 6. QM, South Camp Station. View looking east toward Corps of Engineers headquarters building.

by a tin can. The recording element (potentiometer) had a range from -100°F to + 500°F. No continuous wind observations were made at this station.

d. Forest Station

The Forest Station was in a relatively dense wooded area (Figs. 7 and 8), 3½ miles from the main camp and about 50 yards off a tank trail through the woods. This station was accessible only by use of a tracked vehicle (Otter) or by use of skis or snowshoes. Snow cover in the woods was 2 to 3 feet deep with little or no drifting, since wind speeds within the forest are usually too low to blow snow. Consequently, trees were heavily laden with snow.

A heated shelter was not available at this site. Therefore to protect wind-recording equipment from extreme cold, it was necessary to house it in an insulated box heated by two 600-watt heating elements (wired in series). Electrical power was provided by a 1.6 kilowatt gasoline engine-driven generator.

e. K-22 Station

This station was about 100 yards north of Temporary Building K-22, on an exposed ridge overlooking Hudson Bay, in the northwestern part of the main camp (Fig. 9).

Each of the field stations (ENG, South Camp, excepted) was equipped with an arctic-range thermograph (+50°F to -80°F), maximum and minimum thermometers, Townsend support, and standard instrument shelter. At the K-22 and Forest Stations, Beckman-Whitley Climate Survey wind systems were used with two Esterline-Angus recorders. The Farnworth Lake and QM, South Camp, Stations were provided with Signal Corps GMQ-1 wind systems modified for use with Esterline-Angus recorders.

f. Canadian Meteorological Station

The Canadian Meteorological Station was at the airfield near the hangar, about 150 yards from the nearest obstruction. The temperature data were obtained by a thermograph in an instrument shelter. Wind speed was measured by a 3-cup anemometer approximately 70 feet above the ground, on top of the control tower at the northwest corner of the hangar.

4. Kinds of Data Collected

Continuous temperature data were obtained from the six stations for the 23-day period beginning 16 January 1955 and ending 7 February 1955. In the few instances where temperature data are missing, the cause can usually be attributed to mechanical difficulties.

Figure 7. Forest Station. View looking southwest.

Figure 8. Forest Station. View looking east.

Figure 9. K-22 Station. View looking northwest from ridge overlooking Hudson Bay.

The temperature data from the ENG, South Camp Station, are subject to two sources of error:

1) The tin can which served as a radiation shield prevented free air circulation around the thermocouple and probably heated up during periods of sunshine, thereby causing temperatures slightly higher than those of ambient air.

2) A small error was probably introduced by the large range (-100° to $+500^{\circ}$F) of the chart from which the hourly temperatures were read. However, since most of the days during the period of the study had less than six hours of sunshine, and because primary interest in this study is centered on the occurrence of low temperatures (which usually occur during the long night when there is no solar radiation), it is felt that these data are of sufficient interest and accuracy to warrant their use.

In addition to these two possible sources of error, temperatures recorded at this station may also have been influenced by the greater height above the ground of the sensing element (15 feet as compared to 4½ feet at the other stations).

Instruments were calibrated prior to installation and were checked twice each day by observers of the Signal Corps, United States Army. At the Canadian Station, instruments were serviced and maintained, and weather observations were taken, by personnel of the Canadian Meteorological Service.

Figure 9. K-22 Station. View looking northwest from ridge overlooking Hudson Bay.

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Instruments were calibrated prior to installation and were checked twice each day by observers of the Signal Corps, United States Army. At the Canadian Station, instruments were serviced and maintained, and weather observations were taken, by personnel of the Canadian Meteorological Service.

Wind data are available for five of the six stations for the 23-day period. Continuous wind data are not available for the ENG, South Camp, Station, since only occasional, instantaneous wind observations were made.

For the Forest Station wind data are available for only 300 hours of the total possible 552 hours. This was due to the rather frequent breakdown of the generator. When this occurred, the insulated box containing the wind recording instruments quickly cooled until the batteries (the source of power) froze. This situation was corrected during the next visit of the observers, but occasionally several hours passed before the observers arrived.

In addition to the temperature and wind data from the six stations, sunshine data from the Canadian Station are also included, since both wind and diurnal range of temperature are usually directly related to the duration of sunshine and to solar radiation.

5. Analysis of Temperature and Wind Speed Data

In order to compare temperature and wind conditions at the various stations, mean values of temperature and wind speed were computed for each station. In addition, the frequencies and cumulative frequencies of hourly temperatures and wind speeds (in percent) were computed.

a. Temperature

Table I lists the true daily mean temperatures, and daily maximum and minimum temperatures, for each station for the 23-day period of record 16 January to 7 February 1955. Table II lists the mean, mean maximum, and mean minimum temperatures for each station for the period. These data are shown in graph form in Figure 10. The graphs show that when temperatures are considered, the coldest stations were QM and Farnworth, while the warmest were Forest, ENG, and Canadian. This is to be expected, since the QM and Farnworth Stations were lower than the surrounding terrain, and cold air drainage and accumulation take place through cooling of the earth's surface during the long winter nights. In addition, these stations, because of slightly lower elevations, were more sheltered from wind which tends to destroy the ponding of cold air.

The higher temperatures recorded at the ENG, Forest, and Canadian Stations may be explained in several ways. The thermocouple of the ENG Station was undoubtedly influenced by the effects of radiation on the tin can which covered it. In addition, the thermocouple was at a higher elevation above the ground where the frequency of higher wind speeds was probably greater and the effect of cold air drainage was negligible. The Forest Station plainly showed the warming influence of the vegetation. Although the lower wind speeds which occurred at

TABLE I: Daily Mean, Maximum and Minimum Temperatures at Six Stations
Fort Churchill, Canada, 16 January - 7 February 1955.
(^{o}F)

Station		January																February						
		16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	1	2	3	4	5	6	7
Farnsworth	Max	-11	- 2	-26	-21	- 5	- 3	-16	-26	-29	-29	-27	-28	-29	-30	-17	-16	-28	- 5	7	13	- 3	-21	-21
	Min	-29	-25	-33	-35	-17	-21	-26	-32	-35	-34	-32	-32	-33	-39	-42	-37	-38	-34	-10	- 3	-21	-40	-45
	Mean	-21	-15	-29	-29	-10	-11	-20	-30	-33	-32	-30	-30	-31	-33	-29	-25	-35	-19	- 3	8	-12	-34	-32
QM, So. Camp	Max	-11	- 3	-27	-23	- 5	- 6	-17	-28	-30	-30	-28	-29	-29	-30	-18	-17	-28	- 4	9	15	- 3	-26	-20
	Min	-32	-30	-34	-37	-18	-24	-27	-34	-37	-35	-34	-33	-34	-39	-44	-37	-40	-35	- 5	- 2	-20	-40	-45
	Mean	-21	-17	-31	-30	-10	-13	-22	-31	-34	-33	-31	-30	-32	-34	-30	-25	-36	-18	- 1	8	-11	-34	-31
ENG, So. Camp	Max	- 7	0	-26	-20	- 1	- 1	M	-11	-27	-25	-21	-21	-22	-23	-10	-10	-23	5	10	16	- 1	-21	-15
	Min	-28	-28	-35	-35	-19	-21	M	-29	-33	-38	-30	-28	-29	-35	-40	-35	-35	-30	-11	1	-19	-39	-46
	Mean	-16	-13	-30	-30	- 7	-11	M	-20	-30	-31	-30	-23	-26	-29	-24	-19	-31	-11	- 1	10	- 7	-32	-29
Forest	Max	- 7	- 1	-24	-13	- 1	2	-11	-22	-24	-24	-25	-26	-26	-28	-15	-14	-25	- 1	10	19	2	-16	-16
	Min	-28	-27	-30	-35	-15	-18	-23	-29	-31	-31	-30	-30	-31	-34	-41	-32	-38	-38	0	2	-17	-40	-46
	Mean	-18	-14	-27	-27	- 5	- 7	-17	-26	-29	-28	-28	-27	-28	-30	-30	-20	-33	-18	3	12	- 6	-31	-30
K - 22	Max	- 9	- 2	-26	-16	- 2	0	-14	-25	-27	-24	-26	-25	-27	-28	-17	-16	-29	- 4	9	16	- 3	-26	-19
	Min	-29	-28	-33	-32	-14	-19	-24	-31	-32	-31	-31	-30	-30	-37	-41	-34	-37	-34	- 5	- 2	-25	-38	-42
	Mean	-19	-16	-30	-27	- 7	-10	-18	-28	-30	-28	-29	-27	-29	-32	-29	-22	-34	-18	1	10	-11	-32	-26
Canadian	Max	- 7	1	-23	-20	1	2	-11	-21	-26	-22	-23	-23	-25	-26	-14	-13	-28	3	14	19	2	-22	-15
	Min	-26	-24	-29	-30	-19	-16	-20	-28	-30	-28	-29	-28	-28	-34	-42	-33	-35	-30	- 1	3	-17	-32	-39
	Mean	-17	-12	-26	-25	- 5	- 6	-15	-25	-28	-25	-26	-25	-27	-29	-26	-21	-32	-14	4	13	- 6	-28	-25

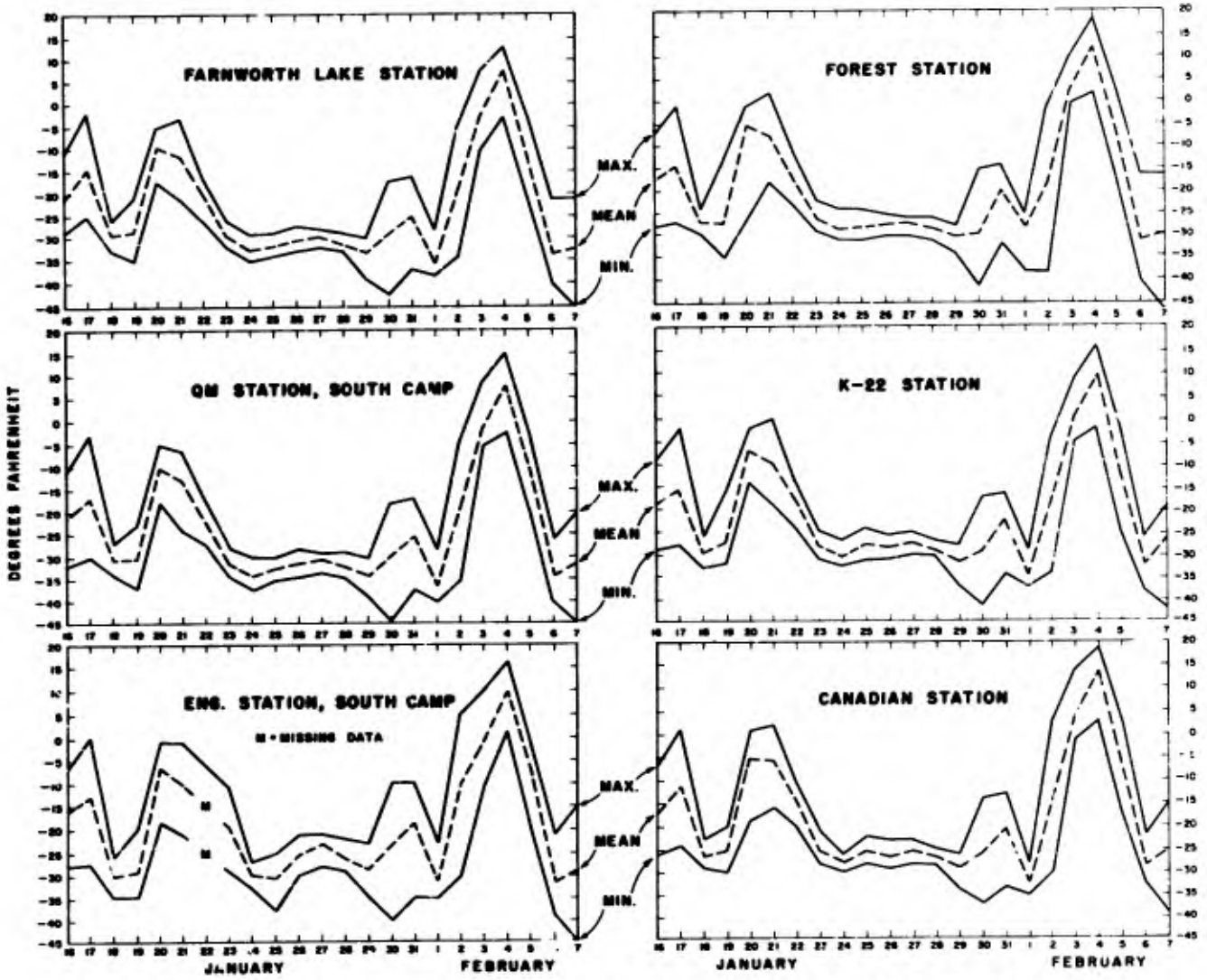

Figure 10. Daily maximum, minimum and mean temperatures (°F) at six stations Fort Churchill, Canada, 16 January - 7 February 1955

TABLE II: Mean Maximum, Mean Minimum and Mean Temperatures for Six Stations

Fort Churchill, Canada, 16 January - 7 February 1955
(°F)

Station	Mean Maximum	Mean Minimum	Mean
Farnworth	-16.2	-30.1	-23.3
QM, South Camp	-16.9	-31.1	-23.8
ENG, South Camp	-11.5	-29.2	-20.0
Forest	-12.4	-27.9	-21.4
K-22	-14.8	-28.7	-21.3
Canadian	-12.0	-25.9	-18.5

this station would generally increase conditions favorable for the occurrence of lower temperatures, the vegetation radiated heat to the ground, thereby reducing the net loss of terrestrial radiation. This prevented extreme cooling of the surface as takes place in open, snow-covered areas. The Canadian Station, although located 150 yards from the nearest building, probably was influenced by the proximity of the main camp installations, and by its higher elevation.

K-22 Station recorded temperatures generally between those of the warmest and coldest stations. This station was on an exposed ridge overlooking Hudson Bay, and was not subjected to the influence of cold air drainage as were stations at lower elevations and farther inland. At no time during the period of study did calm conditions occur at this station, the wind preventing the accumulation of cold air.

Frequencies and cumulative frequencies (in percent) of hourly temperatures at each station are shown in Figures 11 and 12.

The greatest frequency of temperatures occurred in the range from -25°F to -35°F. The most frequent temperature values at each station were as follows:

Farnworth	-32°F		
QM	-32°F	and	-34°F
ENG	-29°F		
Forest	-29°F		
K-22	-30°F	and	-31°F
Canadian	-28°F		

These values further testify to the differences in temperatures recorded

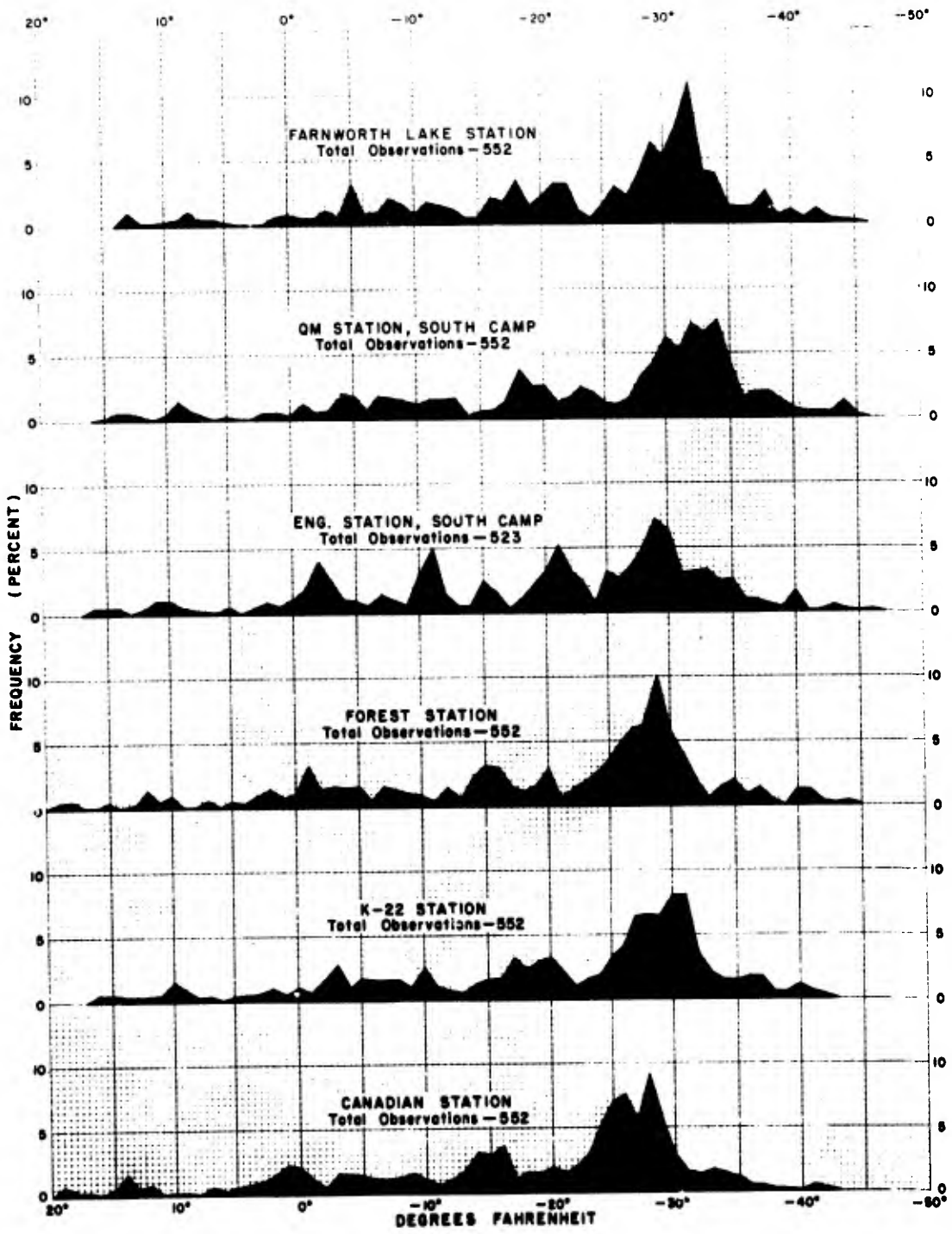

Figure 11. Frequencies of Hourly Temperatures at Six Stations
Fort Churchill, Canada, 16 January - 7 February 1955

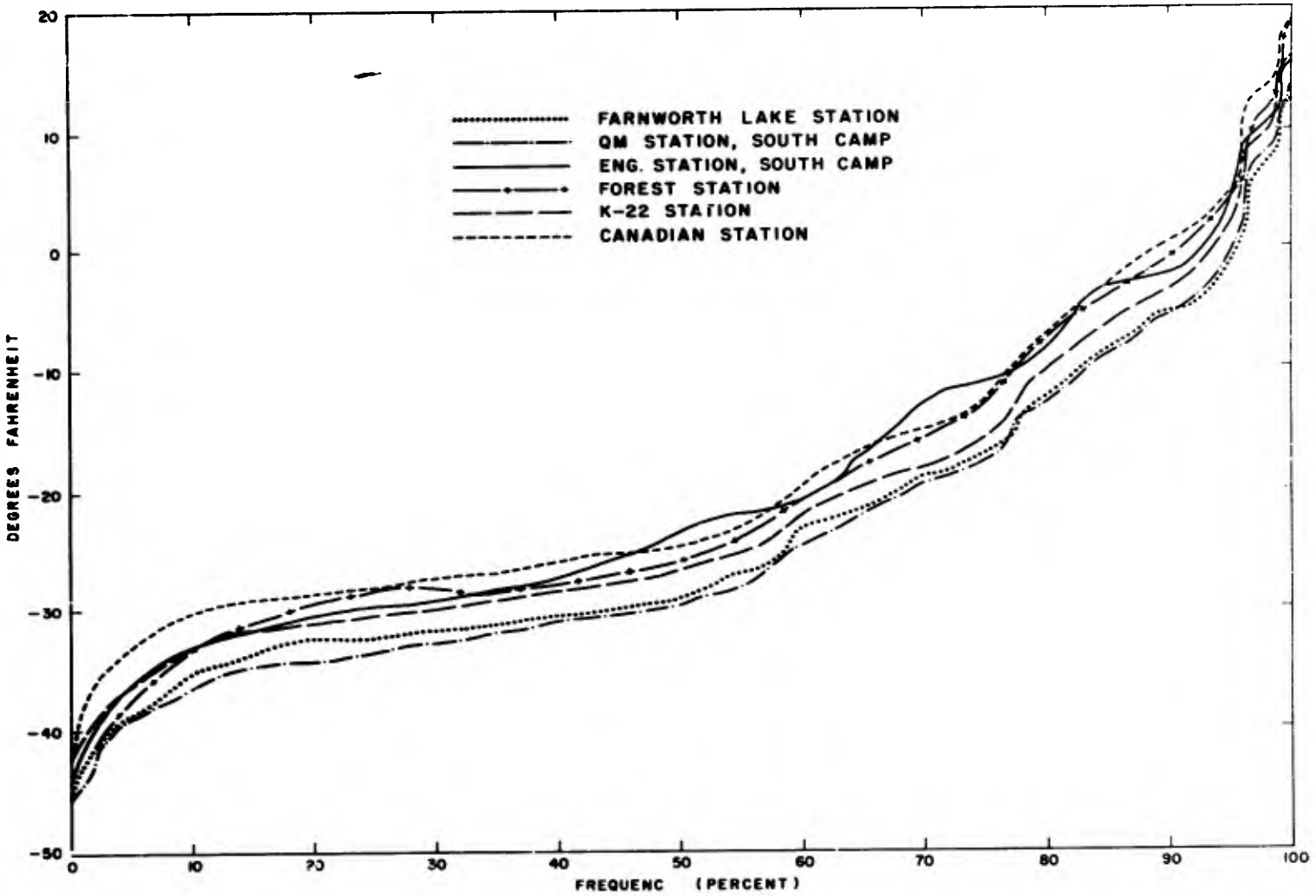

Figure 12. Cumulative frequencies of hourly temperatures (%) at six stations Fort Churchill, Canada, 16 January - 7 February 1955

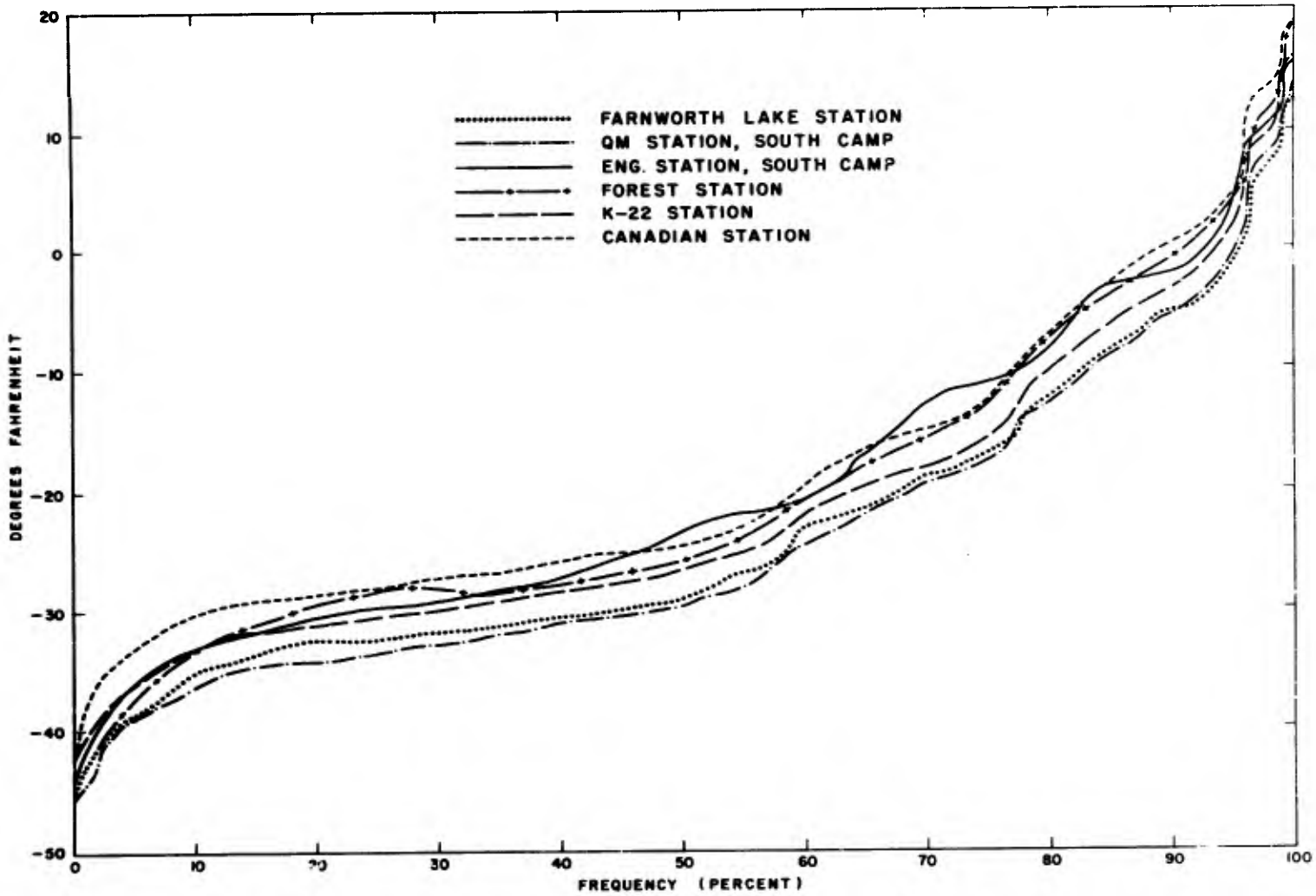

Figure 12. Cumulative frequencies of hourly temperatures (%) at six stations Fort Churchill, Canada, 16 January - 7 February 1955

at the various stations. From the graphs on Figure 11 it may be seen that the highest temperature observed during the period (19°F) occured at the Forest and Canadian Stations.

Figure 12 shows the cumulative frequencies of all temperatures recorded at each station for the period of study. From this figure, it is readily seen that the Farnworth and QM Stations were colder than the others. For example, temperatures at or below -20°F occurred nearly 70 percent of the time at these two stations, but only about 60 percent of the time at the ENG, Forest, and Canadian Stations, and 65 percent at K-22. It may also be noted from this graph that differences between stations were least at the extreme high and extreme low temperatures, i.e., above 10°F and below -40°F.

Figure 13 portrays graphically the difference between the cumulative frequency of temperatures at the field stations and at the Canadian Station, which serves as a base. It is apparent from the graph that the Canadian Station was the warmest of the six stations utilized in the study, since the frequency of very low temperatures is greater at the five field stations than at the Canadian Station.

The greatest frequency difference between the Canadian Station and field stations occurs at a temperature of -30°F. The frequency of hourly temperature at or below -30°F is about 37 percent greater at QM, South Camp Station than at the Canadian Station.

b. Wind Speed

Wind speed data for five stations (data were not available for ENG Station) exhibit even greater differences than the temperature data. Table III lists the mean daily wind speed and the maximum and minimum wind speeds that occurred each day of the observation period. The mean wind speed for each station is presented in graph form in Figure 14. The cumulative frequency of wind speeds (in percent) is shown on Figure 15.

The greater values of the daily mean wind speeds of K-22 and Canadian Stations are easily recognized on Figure 14. The higher wind speeds recorded at the Canadian Meteorological Station are in agreement with previous findings. Research performed for the Office of The Quartermaster General* showed that under stable conditions wind speed 5 feet above the ground will be approximately 40 percent of the wind speed 70 feet above the ground. Under convective conditions the wind speed at 5 feet will be about 70 percent of that at 70 feet.

*See Number 8 in Bibliography.

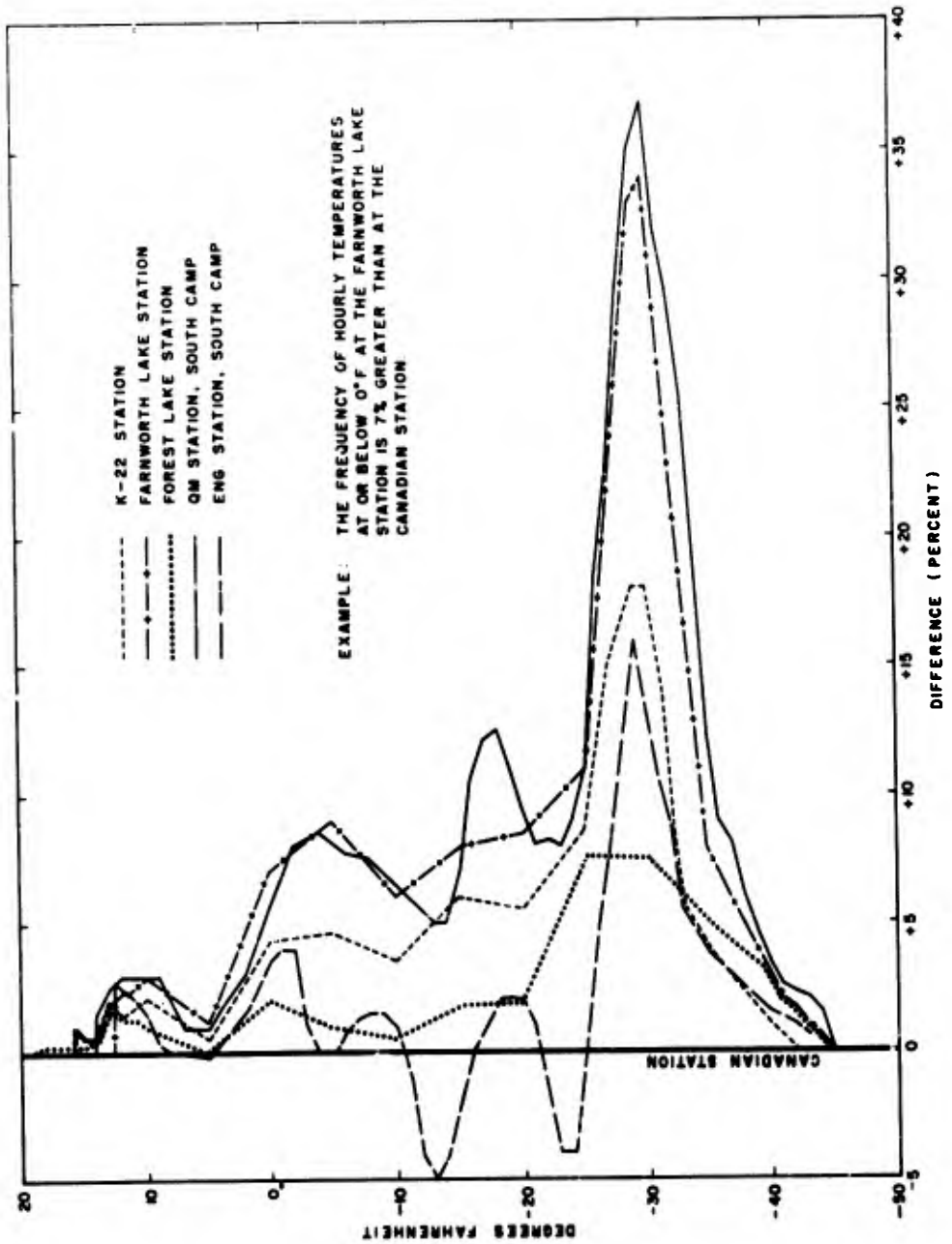

Figure 13. Departures of cumulative temperature frequencies of five field stations from those of Canadian Station Fort Churchill, Canada, 16 January - 7 February 1955.

TABLE III: Daily Mean Wind Speeds, and Daily Maximum and Minimum Wind Speeds for Five Stations*
Fort Churchill, Canada, 16 January - 7 February 1955
(mph)

Stations		January 16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	February 1	2	3	4	5	6	7	Mean of Period
Farnworth	Max	M	17	14	17	19	21	19	16	15	?	16	18	13	11	12	12	5	M	7	9	21	16	8	14.0
	Min	M	0	0	3	0	5	2	9	0	0	0	7	2	0	0	0	0	M	0	0	9	0	0	1.8
	Mean	M	10.4	5.0	11.7	10.7	11.9	7.6	12.3	5.0	4.3	6.1	13.8	8.6	3.0	6.2	5.0	1.0	M	2.4	6.1	16.0	6.7	2.2	7.5
QM, So. Camp	Max	17	28	22	15	19	23	29	9	11	13	13	19	17	15	11	12	6	12	7	9	19	17	6	15.2
	Min	6	9	6	4	7	1	5	1	1	3	1	9	1	0	0	0	0	2	0	3	8	0	0	2.9
	Mean	11.4	16.3	14.8	9.1	13.4	11.2	13.5	6.7	7.3	9.3	8.0	15.9	10.7	9.3	5.3	7.2	1.7	6.2	3.1	5.4	14.0	7.6	4.3	9.2
Forest	Max	1	4	7	3	3	2	M	M	M	M	M	0	2	2	M	M	M	M	M	0	0	0	0	1.8
	Min	0	0	2	0	0	0	M	M	M	M	M	0	0	0	M	M	M	M	M	0	0	0	0	0.7
	Mean	<1	1.3	4.4	1.3	2.0	<1	M	M	M	M	M	0	<1	<1	M	M	M	M	M	0	0	0	0	0.6
E-22	Max	19	23	19	15	22	15	26	17	15	24	25	35	33	29	26	26	17	31	24	25	42	38	19	24.6
	Min	8	6	8	5	7	5	14	7	7	6	11	13	13	9	8	5	9	14	11	8	21	8	6	9.1
	Mean	11.1	11.3	14.3	11.2	15.7	12.5	18.4	11.1	8.7	16.6	18.9	28.8	22.1	20.8	18.0	18.5	12.8	21.1	14.7	17.6	34.5	19.3	11.1	16.9
Canadian	Max	24	24	22	22	25	20	29	25	22	25	25	38	36	30	31	28	20	30	20	23	33	28	20	26.1
	Min	5	13	18	6	10	2	20	10	15	16	18	20	13	16	7	2	5	12	9	8	16	12	0	11.0
	Mean	12.5	18.0	20.3	15.5	19.0	13.9	23.4	17.8	18.9	20.4	21.0	29.4	22.5	21.4	19.8	16.4	12.9	21.3	14.2	15.9	23.2	17.5	11.7	18.6

*M = Missing data

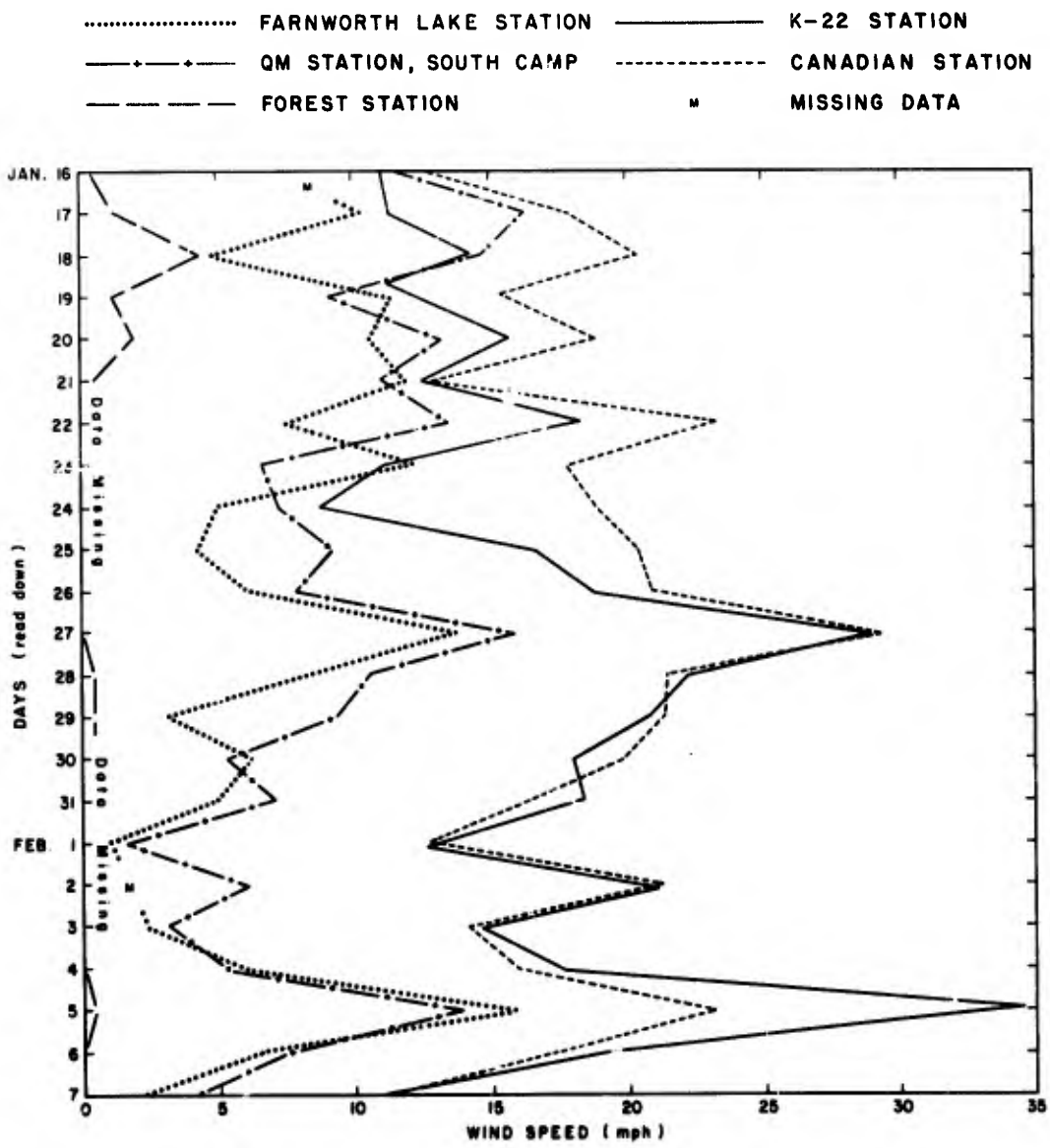

Figure 14. Mean daily wind speed for five stations
Fort Churchill, Canada
16 January - 7 February 1955

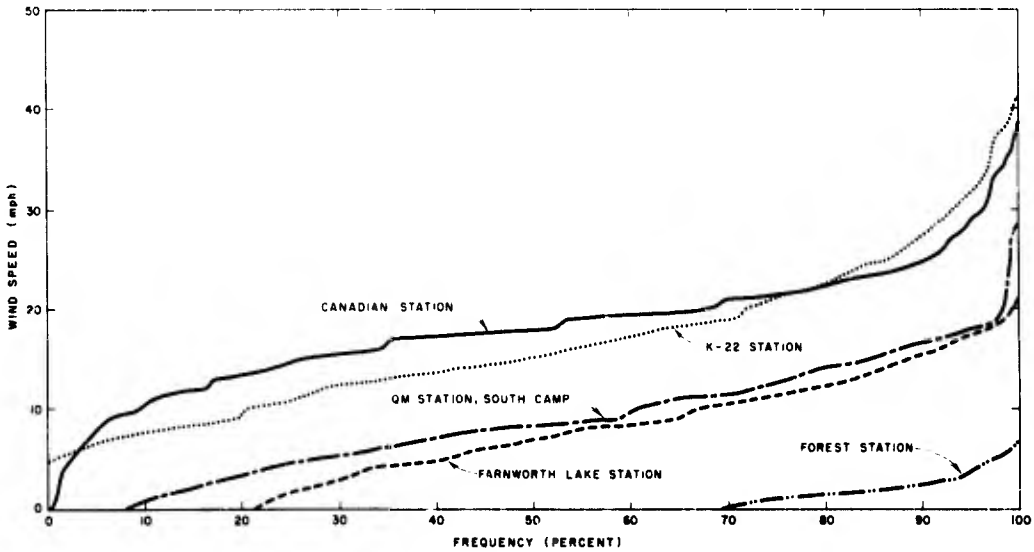

Figure 15. Cumulative frequencies of hourly wind speeds at five stations. Fort Churchill, Canada. 16 January - 7 February 1955

The highest mean daily wind speed recorded during the period, 34.[illegible] mph, occurred at K-22 Station on 5 February. On this day the mean wind speed at the Forest Station was less than 1 mph, an indication of the protection afforded by the vegetation surrounding this station. In general, the highest daily mean wind speeds occurred at the K-22 and Canadian Stations, and the lowest at the Forest Station. Farnworth and QM South Camp Stations had values between the two extremes.

From an examination of Figure 15 it is apparent that the greatest frequency of strong winds occurred at the K-22 and Canadian Stations. At K-22, the lowest wind speed recorded was 5 mph, and also the strongest hourly wind recorded during the study, 42 mph, was observed at this station. At the Canadian Station, calm conditions occurred less than 1 percent of the time, and the most frequent wind speeds were in the order of 15 to 25 mph, as compared to 10 to 20 mph for the K-22 Station.

Nearly 70 percent of the observations from the Forest Station were calm. Although almost half of the observations are lacking from this station, comparison of the data with those from the other stations indicates that the wind speed data from the Forest Station are reliable. For example, on 27 January at 2000 hours the Forest Station had calm conditions. At the same time a wind speed of 35 mph was recorded at the K-22 Station, 38 mph at the Canadian Station, 12 mph at Farnworth, and

19 mph at QM. Comparison of the Forest Station data with those from other stations for other times and days produced much the same result. It may be concluded, therefore, that if the remainder of the data were available for the Forest Station, these data would continue to show an overwhelming preponderance of calms for that station. At no time during the period of study did strong winds occur at this station, the highest recorded being only 7 mph. The lack of high wind speeds at the Forest Station is further substantiated by the fact that throughout the period of the study the snow remained on the trees (Figs. 7 and 8).

The Farnworth Station was the second (after the Forest Station) least windy of the five stations, having calm conditions over 20 percent of the time. The K-22 and Canadian Stations, exposed to full effects of the wind, had by far the greatest occurrence of strong winds; the Farnworth and QM Stations, at more sheltered locations, had fewer occurrences of strong winds; and the Forest Station, protected on all sides from prevailing winds, had a very small frequency of even light winds.

6. Temperature and Wind Combinations

The occurrence of strong winds in combination with low temperatures is one of the more critical conditions soldiers must face in the Arctic and subarctic during winter. Windchill, which may be defined as the cooling effect of air movement and low temperatures in combination, is of vital concern in the development of proper clothing and equipment for use by troops in cold environments. Windchill must be considered by physiologists, biophysicists, and other scientists who concern themselves mainly with the reaction of the body to the extreme cold, or with the protection afforded by clothing and equipment. It has long been known that, with identical temperatures, heat loss from the body occurs more rapidly during times of strong winds. To illustrate this point, the following example is offered:

Temperature (°F)	Wind speed (mph)	Windchill (kg-cal/m^2/hr)
-20	5	1438
-20	30	2112

To provide a basis for studying the occurrence of wind speeds at various temperatures, the relative distribution of wind and temperature data from the stations where both wind and temperature were recorded are presented in graph form in Figures 16, 17, and 18. These figures show the actual occurrences of wind speeds (grouped according to Beaufort scale) in combination with temperature groups (5 degree (F) intervals), plotted in three-dimensional form.

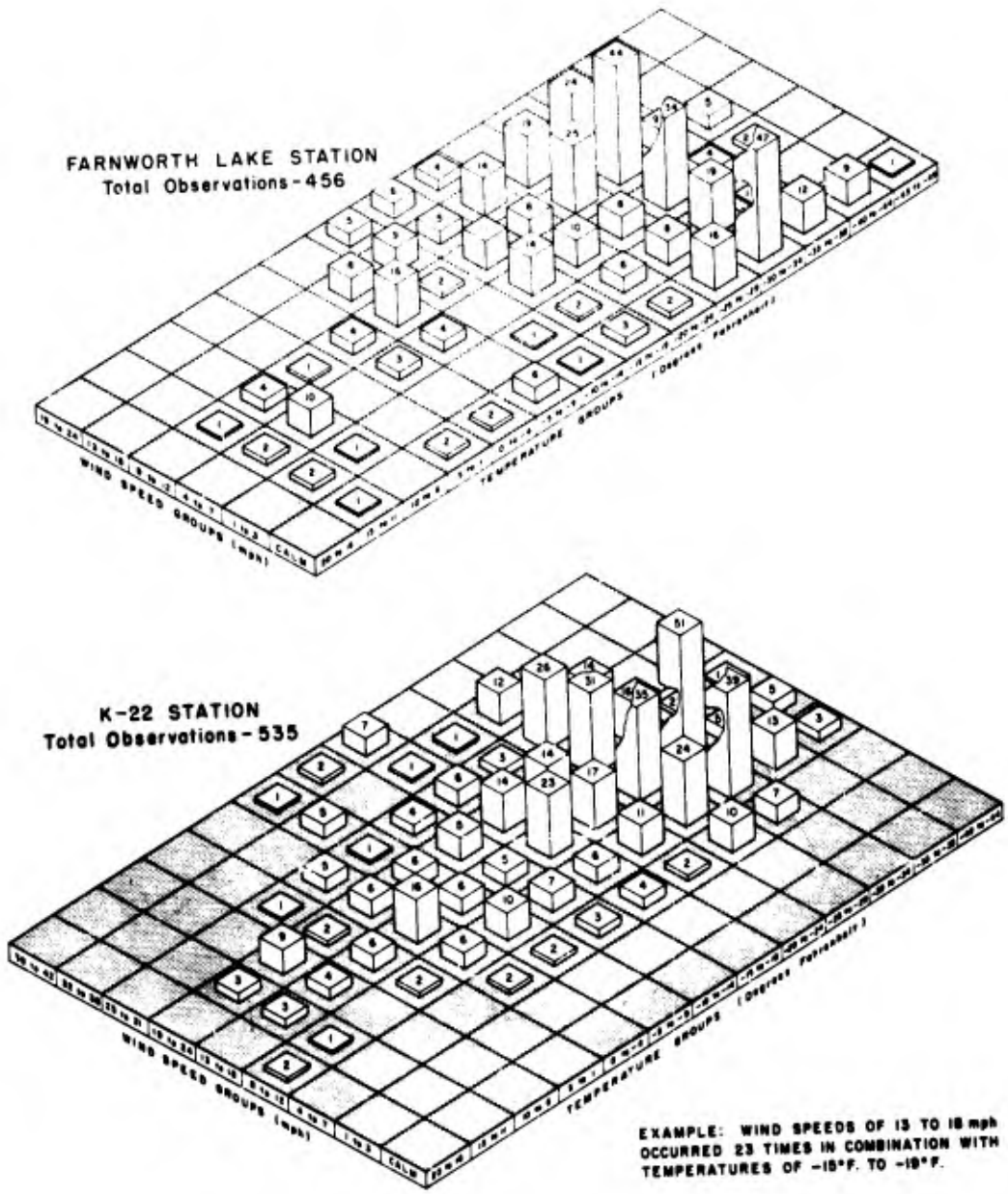

Figure 16. Occurrences of wind speeds at various temperatures: Farnworth and K-22 Stations, Fort Churchill, Canada 16 January - 7 February 1955

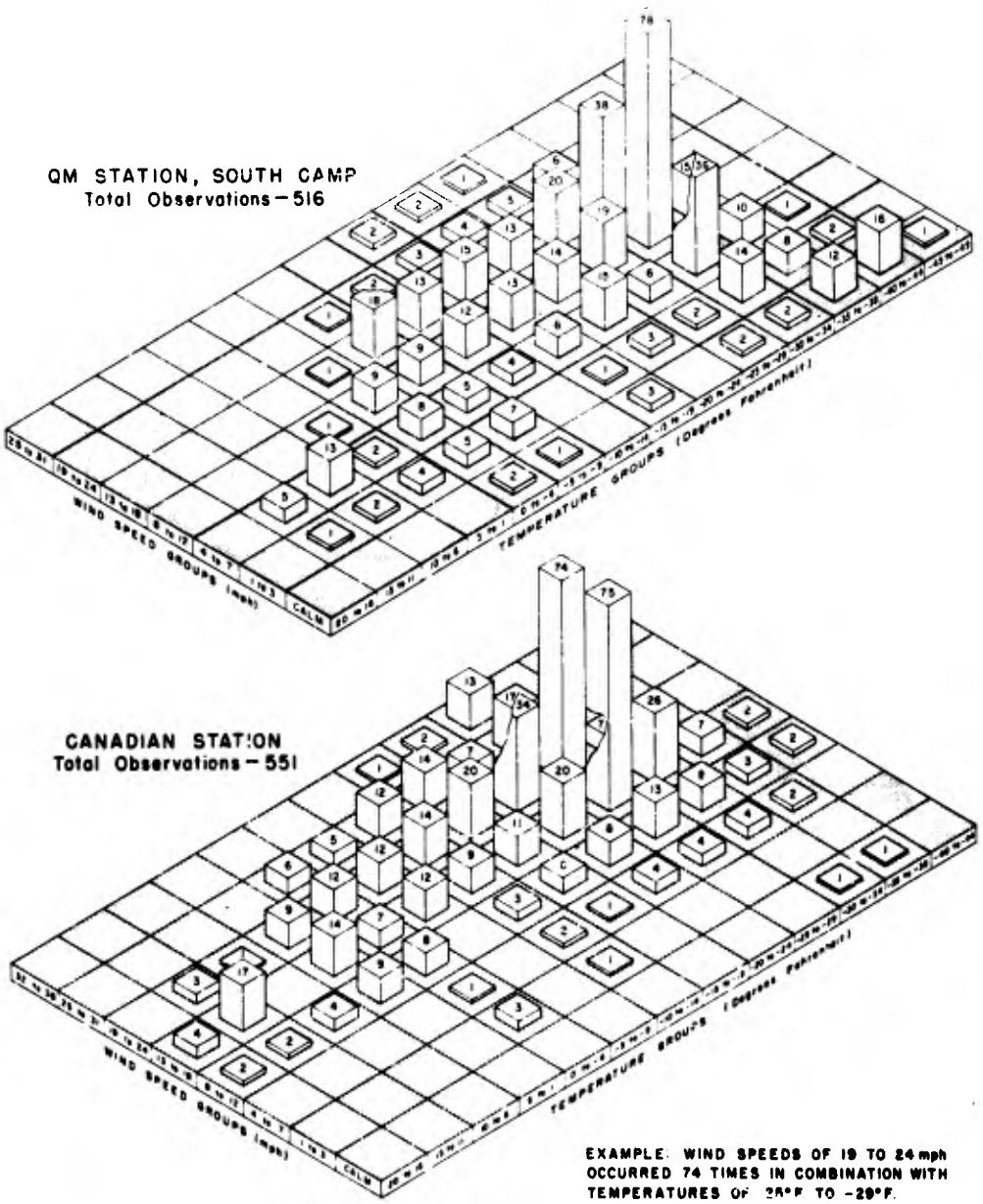

Figure 17. Occurrences of wind speeds at various temperatures: QM (South Camp) and Canadian Stations, Fort Churchill, Canada 16 January – 7 February 1955

It is usually assumed that with the occurrence of very low temperatures (i.e., at or below -25°F), calm conditions exist much of the time, and that this lack of wind compensates in part for the extreme cold. From a study of the graphs it is immediately apparent that, with the exception of the Forest Station, higher wind speeds occur in combination with low temperatures as frequently as with higher temperatures.

For example, at the K-22 Station (Fig. 16) there were 51 occurrences of wind speeds between 13 and 18 mph in combination with temperatures between -30° and -34°F. This was the maximum occurrence of any combination of a wind speed group with a temperature group at this station. From this graph it is evident that the greatest number of occurrences of strong winds was in combination with temperatures below -25°F, and relatively very few occurrences of strong winds at temperatures above 0°F. There was no significant increase in the number of lower values of wind speeds, or occurrence of calms at temperatures below -25°F. In fact, there were no calms reported at this station during the period of record, although temperatures below -40°F were recorded.

An examination of the graph for the Farnworth Station (Fig. 16) shows the same pattern even though this station was located in an area where calm conditions would be expected much of the time, especially during the hours of darkness.

From the graph for the QM, South Camp Station (Fig. 17) it may be noted that the maximum occurrence (78) is for wind speeds of 8 to 12 mph in combination with temperatures of -30° to -34°F. In this temperature class the next greatest occurrence (38) is not at lower wind speeds, as might normally be expected, but at higher wind speeds of 13 to 18 mph. During the entire period, at this station, at this particular temperature grouping - between -30° and -34°F - calms occurred only twice, while the total number of occurrences of wind speeds equal to, or greater than, 4 mph was 152. It should be emphasized that this station was much less windy than either the K-22 or Canadian Stations, and that a greater frequency of calms could normally be expected.

At the Canadian Station (Fig. 17) the most frequent combination was the wind speed group of 13 to 18 mph with the temperature group, -25° to -29°F. The next most frequent combination was not at a weaker wind group and higher temperature, but actually at stronger winds with the same temperature group.

The vegetation at the Forest Station had a pronounced influence on both temperature and wind. Almost 70 percent of the wind speed observations at this station were calms, and 20 percent of the calms were at temperatures from -25° to -29°F (Fig. 18).

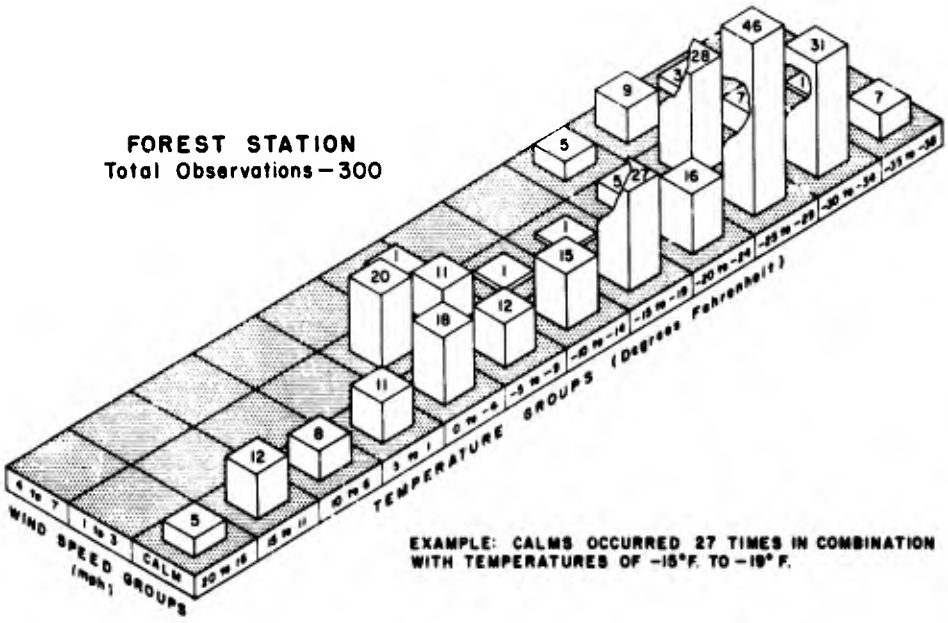

Figure 18. Occurrences of wind speeds at various temperatures. Fort Churchill, Canada. 16 January - 7 February 1955.

7. Relationship of Temperature Range, Sunshine, and Wind Speed.

In order to provide information directly related to the diurnal temperature range, the duration of sunshine (radiation data were not available) for each day during the period of record was studied. It was expected that there might be a direct correlation between the number of hours of sunshine on any one day and the range of temperature for that day, and that the greater the number of hours of sunshine the larger would be the temperature range. This did not prove to be true. The data on duration of sunshine, as recorded at Canadian Station are shown in graph form in Figure 19.

During the period of the study the maximum number of hours of sunshine that occurred on any one day was slightly more than 7 hours (on the 1st and 6th days of February), while on 3 days (20 January, and 4 and 5 February) no sunshine at all was recorded. On most days the duration of sunshine was between 2.5 and 3.5 hours.

The diurnal temperature range (see Table I) was plotted against hours of sunshine for the Canadian Station. From this it was immediately evident that there was little correlation between the number of hours of sunshine and diurnal temperature range during the 23-day period of study.

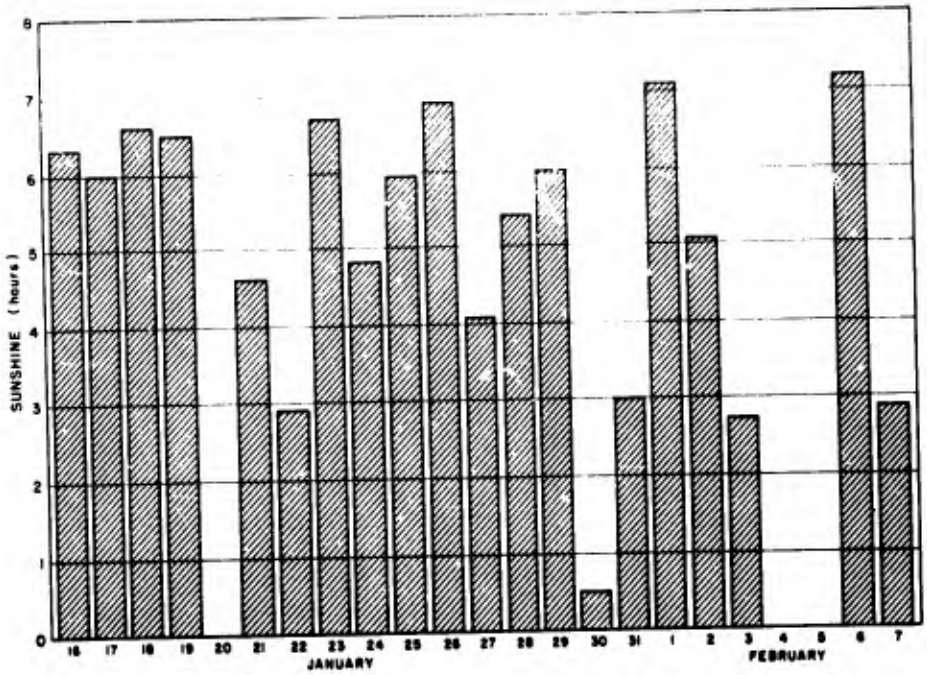

Figure 19. Duration of sunshine (hours)
Fort Churchill, Canada.
16 January - 7 February 1955

On those days when there was little sunshine, or none at all, some of the largest diurnal temperature ranges occurred. This lack of correlation was explained through study of daily weather maps. Usually large diurnal temperature ranges were associated with cyclonic activity (low pressure systems, fronts, and/or troughs) passing over the area. With activity of this nature there was almost always considerable cloudiness, which reduced the number of hours of sunshine to a minimum, with the result that many of the days which had a large diurnal range in temperature also had little or no sunshine.

This same relation holds true with regard to diurnal wind variation. Strongest winds were associated with cyclonic activity (occurring shortly before, during, or after passage of a low pressure system, front, or trough), rather than with hours of sunshine.

8. Conclusions

a. Lowest winter temperatures may be expected in open, snow-covered, non-vegetated, areas lower than the surrounding terrain. Into these areas cold-air drainage will take place during hours of darkness when there is little or no cloud cover, and this air will tend

to accumulate in the depressions, causing extremely low temperatures.

b. Highest temperatures may be expected in forests or wooded areas, where the loss of heat by terrestrial radiation is reduced by the trees and the trees themselves radiate some heat, or in areas where wind keeps the air stirred and prevents the accumulation of cold air.

c. Strongest winds occur at higher, exposed locations where there are no obstructions, and weakest winds may be expected in areas of dense vegetation and/or in lower, sheltered areas.

d. The greatest windchill occurs in areas where winds are strongest, even though these stations have slightly higher temperatures than stations in low-lying areas. The windchill is least in forests or wooded areas.

e. The assumption that calm or nearly calm conditions usually occur simultaneously with extreme low temperatures was not borne out at Fort Churchill during the period of the study. In order to substantiate these findings, further investigations are required at Fort Churchill and at other Arctic and subarctic stations.

f. There was no correlation between number of hours of sunshine and diurnal temperature range. The greatest ranges occurred with the temperature changes associated with cyclonic activity. This was also true of the diurnal variation in wind speed.

9. Acknowledgments

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All maps and charts used in this study were drafted by Mr. Roland Frodigh, Cartographic Draftsman, under the direction of Mr. Andrew Hastings, Chief, Cartographic Section.

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For the period of study, there was no correlation between hours of sunshine and diurnal temperature range, or between hours of sunshine and diurnal wind variation.

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