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Technical Report 161

SURVEY OF ARCTIC AND SUBARCTIC TEMPERATURE INVERSIONS

by

Michael A. Bilello

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U.S. ARMY MATERIEL COMMAND

COLD REGIONS RESEARCH & ENGINEERING LABORATORY

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PREFACE

This study was conducted under the general supervision of Dr. R.W. Gerdel, former Chief, Environmental Research Branch, and Dr. A. Assur, Chief Scientist, USA CRREL.

The machine-tabulated data used in the survey were processed and prepared at the Weather Bureau National Weather Records Center, Asheville, North Carolina. The research was requested and funded by the Defense Atomic Support Agency under Nuclear Weapons Effects Research subtask number 02.046.

The author wishes to thank Mr. Roy Bates for his assistance in the preparation of the tables.

USA CRREL is an Army Materiel Command laboratory.

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SUMMARY

This study provides a statistical analysis of available data on Arctic and subarctic inversions, and includes data from locations in Canada, Greenland, and Alaska. The analysis considers inversions with respect to frequency, base height, thickness, base temperature, and temperature gradient.

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Introduction

A temperature inversion is defined meteorologically as a layer of air in which the temperature increases with altitude. As noted in the Glossary of Meteorology (1959), the principal characteristic of an inversion layer is its marked stability, which allows very little turbulent exchange to occur within it.

Wexler (1936) points out that during clear, calm nights, the temperature of a snow surface falls below the temperature of the air. He describes how the snow surface radiates energy practically as a black body and receives, by conduction from the snow and air and also by atmospheric radiation, less energy than it loses through its own radiation; consequently, its temperature decreases.

In polar regions, inversions are observed throughout the year, but are usually steeper during the cold period of the year than during the warm period. The bases of these inversions are not always located at the earth's surface. When the layers adjacent to the earth's surface are warmed, an inversion may still persist, but the base then is located off the ground. The heights to which inversions extend and the intensity of temperature-increase-with-height vary from place to place and from month to month.

The purpose of this study is to provide a statistical analysis of available data on Arctic and subarctic inversions. The study includes data from locations in Canada, Greenland, and Alaska, and the analysis considers inversions with respect to frequency, base height, thickness, base temperature, and temperature gradient.

A major study of this type was conducted by the U.S. Navy (1963). The resulting Marine Climatic Atlas of the World presents climatic data for 47 stations throughout the North American Arctic and subarctic. Included are charts giving monthly percentage-frequencies of three intensities of temperature inversion within each of seven layers from the surface to 700 millibars. However, these charts do not provide information on: 1) the thickness of the inversion; 2) standard deviation from the average base height or thickness; 3) temperature at the base of the inversion. To provide this information the author has reanalyzed data for some of the stations in the Navy survey, and included certain areas not covered in the Atlas, such as central Alaska.

Wyatt (1952) notes that inversions in polar regions have also been studied by Sverdrup ("Maud" Expedition to the Arctic Ocean), Flohn (Siberia), Wexler (Alaska), and the German Expedition to the Antarctic in 1911-12. These studies consider only short periods of record and do not provide detailed statistical information for each month of the year.

In an investigation on the distribution of temperature lapse rates over the Arctic regions, Putnins and Choate (1960) considered mean temperatures and the following standard layers: surface to 850 mb, 850-700 mb, 700-500 mb, and 500-300 mb. In the study, daily lapse rates observed during a 1950-51 Russian expedition on drifting ice; mean monthly lapse rates for Fletcher's Ice Island (T-3) observed during 1952-54; and mean seasonal lapse rates for one Iceland, eight Greenland, and five Canadian stations are presented. Mean values on the magnitude of inversions observed at these stations for the intervals noted above also were included.

Recently, Vowinckel (1965) conducted a study on inversions over the Arctic Ocean proper. Radiosonde data from North Pole stations 4, 6 and 7 and for 30 coastal stations surrounding the Arctic Ocean were used. He found slightly stable temperature gradients over the Arctic Ocean in summer changing to very strong inversions by late winter. Unstable gradients predominated over the warm waters of the Norwegian-Barents Sea. The most intense inversions were found over the Beaufort Sea and northwest of the Canadian Archipelago.

In an informal, unofficial USA CRREL Research Note, data on some typical inversions in the Arctic were compiled by the author. These data are appended to this survey (Appendix A).

Selection of stations

A statistical analysis of inversions requires data from upper air soundings made over a reasonable duration of time. Statistical computations on the bulk data were made by computers at the Weather Records Center in Asheville, North Carolina. Except for Thule, the stations used in this study had approximately 8 to 10 years of record available on punch cards. For Thule there was just over 5 years of record. The period of record for some stations was not continuous: e.g., the record for Alert, Canada, is from September 1950 through December 1959 and contains occasional short gaps during the first twenty days of April 1952. These variations have a negligible effect on the overall statistics because the number of soundings, rather than the number of days, was considered in the computations.

Although upper air soundings have been made in the arctic regions of Asia and Europe, only a small portion of the data is available on punched cards. For this reason the study was confined to stations in the Western Hemisphere.

The number of stations that could be studied with the allotted funds was determined by: 1) the format and extent of the statistical computations; and 2) the number of cards used per station. Table I gives the name, elevation, and period of record of each station in the survey. The location of each station is shown in Figure 1. These stations were selected on the basis of geographical coverage, length of record, and availability of punched cards. Also, an attempt was made to include stations omitted in the Naval Marine Atlas.

Table I. Period of record and elevation of stations covered in the survey.

Station	Period of record	Elevation (m)
Alert, Canada	9/50 - 12/59	62
Barrow, Alaska	7/52 - 10/59	7
Churchill, Canada	1/50 - 12/59	35
Clyde River, Canada	1/50 - 4/54; 2/55 - 12/59	3
Coppermine, Canada	1/50 - 2/52; 4/52 - 12/59	9
Coral Harbour, Canada	8/50 - 12/59	53
Fairbanks, Alaska	7/52 - 3/61	133
Mould Bay, Canada	1/50 - 12/59	15
Nome, Alaska	7/50 - 12/59	4
Thule, Greenland	8/52 - 12/57	37
Yakutat, Alaska	1/53 - 12/61	9

Description of data

The machine-tabulated data were divided into two sections, and each section was divided into two parts.

The first section is a monthly tabulation of the number of upper-air soundings taken and the number of inversions observed. Two types of inversions are listed: 1) those in which the base of the inversion is at the earth's surface; and 2) those in which the base is above the surface. Subsequently, these inversions will be

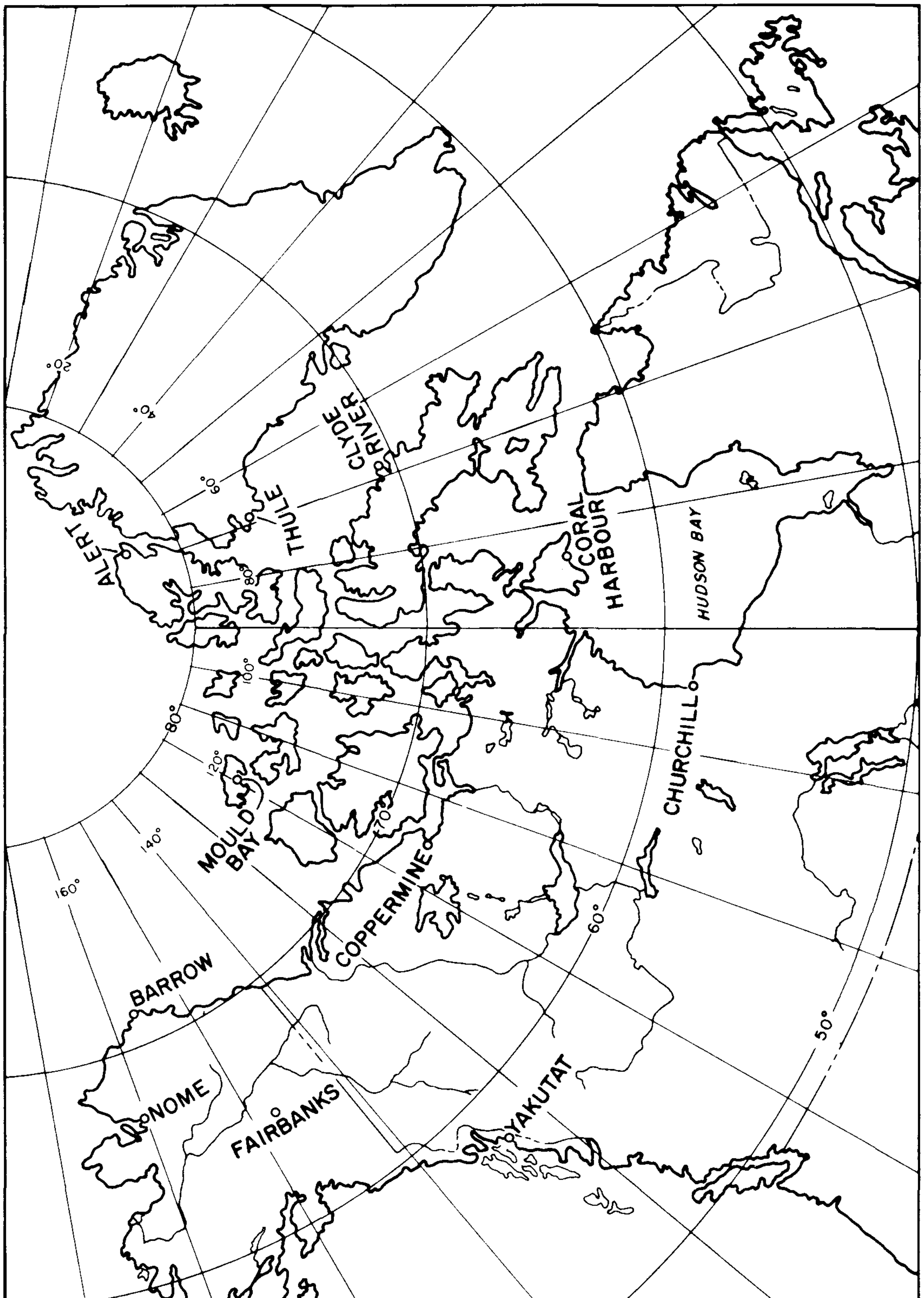

Figure 1. Station map.

identified as type 1 and type 2, respectively. For this survey, any layer having more than one degree (C) increase in temperature per kilometer was considered to be an inversion layer (U.S. Weather Bureau, 1961). Statistical computations for each month and each type of inversion were made. For type 1 the following information was provided:

a. Average thickness of the inversion, in meters, and the standard deviation.

b. Average increase in temperature with height (or temperature gradient), in °C per 100 meters, and the standard deviation.

c. Average temperature at the base of the inversion (i.e., earth's surface) in °C.

Standard deviation was computed from the formula:

$$S = \sqrt{\frac{n\Sigma v^2 - (\Sigma v)^2}{n(n-1)}}$$

where v = the observed values and n = the number of counts.

For inversions in which the base was above the surface (type 2), computations a, b and c were made, and, in addition:

d. Average height of the base of the inversion, and the standard deviation.

Two upper soundings are normally made each day: one at 2400 and another at 1200 Greenwich Meridian Time. Unfortunately, only the 2400 GMT observations were available on punch cards for all the stations except Nome and Fairbanks, Alaska. The cost of punching the 1200 GMT data was too expensive to justify its inclusion in the study. Since locations in high latitudes experience long periods of light and dark, omission of diurnal variations is negligible. However, for the purpose of noting diurnal variations at lower latitudes, statistical analyses of both 2400 and 1200 observations were conducted for Nome and Fairbanks, Alaska.

The second section of the machine-tabulated data gives the number of inversions in terms of thickness and temperature difference from the base to the top of the inversion; increments of 50 meters thickness and 1C temperature difference were used.

This second section was divided into two arbitrarily defined time periods: 1) the months November through April and 2) the months May through October. For those stations located in the Arctic, the first period defines approximately the months of continuous dark, and the second period the months of continuous light. For stations at lower latitudes these periods define the relative cold and warm months, respectively.

Tabular presentation

The data are presented here as Tables II, III and IV. The major portion of this statistical survey consists of a set of these tables for each station studied.

Table II gives statistical summaries by month for inversions with the base at the earth surface (type 1), including: number of soundings, number and frequency of occurrence, average thickness and temperature gradient, and standard deviation of thickness and temperature gradient.

Assuming that the observations on thickness and temperature gradient are fairly symmetrical with respect to the mean (or average) value, the standard deviation gives a measure of the range within which a large proportion of the reports will be included. In a normal distribution the interval from the distance of one standard deviation below the mean to the distance of one standard deviation above the mean will include about 2/3 of the observations (Ezekiel and Fox, 1959).

Since the lower limit of the inversion thickness in Table II is finite and the upper limit unbounded, the data are probably not normally distributed. This means that fewer than 2/3 of the observations can be expected to occur within the limits defined by the standard deviation.

The average inversion temperature gradient (the rate of increase in temperature with height) is the mean of the gradients for all the inversions, assuming a uniform increase in temperature from the base to the top for each individual inversion.

Table III gives the same information for type 2 inversions, with two more columns giving the average height of the base of the inversion above the surface and the standard deviation of the base height. Base height plus thickness gives the average height of the top of the inversion.

Table IV gives the frequency of inversion occurrence in terms of various thicknesses and temperature gradients.

The machine data were analyzed in terms of 50-meter increments of inversion thickness, but are presented in Table IV in increments of 200 meters.

The breakdown given in Table IV is somewhat detailed. The format, however, allows the user to combine categories as required.

Graphical presentation of data

Types of figures adaptable to graphical presentation of the inversion data are shown in Figures 2, 3 and 4. The data for Alert have been presented in graphical form as an example.

Note that the sloped lines in Figures 2C and 3C extend to 500 meters. This level was arbitrarily selected and does not indicate specific inversion thicknesses. To compute temperature gradient in terms of °C/100 meters, subtract the temperature at 500 meters from that at the base and divide by five.

Discussion of results

Seasonal variations. Inspection of the data in Tables II and III shows differences in inversion frequency and physical characteristics between the six cold months (November through April) and the six warm months (May through October). The outstanding difference is the variation in inversion thickness; inversions during the cold months are deeper (extend to a greater height) than those observed

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On page 5, next-to-last paragraph, add:

In Figures 5 and 6 only the 2400 Z data were used in the tabulations for Fairbanks and Nome.

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Type 1 inversions occur more frequently during cold rather than warm months. In general, the opposite is true for type 2 inversions.

Temperature gradients (inversion steepness) at most locations are greater during the cold period of the year. This is true for both type 1 and type 2 inversions.

It is difficult to make a precise separation of the year into "cold" and "warm" 6-month periods, but the physical characteristics of the inversions change sufficiently between April and May and between October and November to justify a separation at these times.

Regional variations. Regional variations in inversion characteristics were analyzed using the seasonal break. The results are shown in Figures 5 through 8.

From Figure 5 it can be seen that throughout the year type 1 inversions occur most frequently at Alert and Coral Harbour and decrease in frequency westward. Note that two frequencies (in percent) are shown for each station, each referring to a 6-month period. The average of the two values gives the annual frequency.

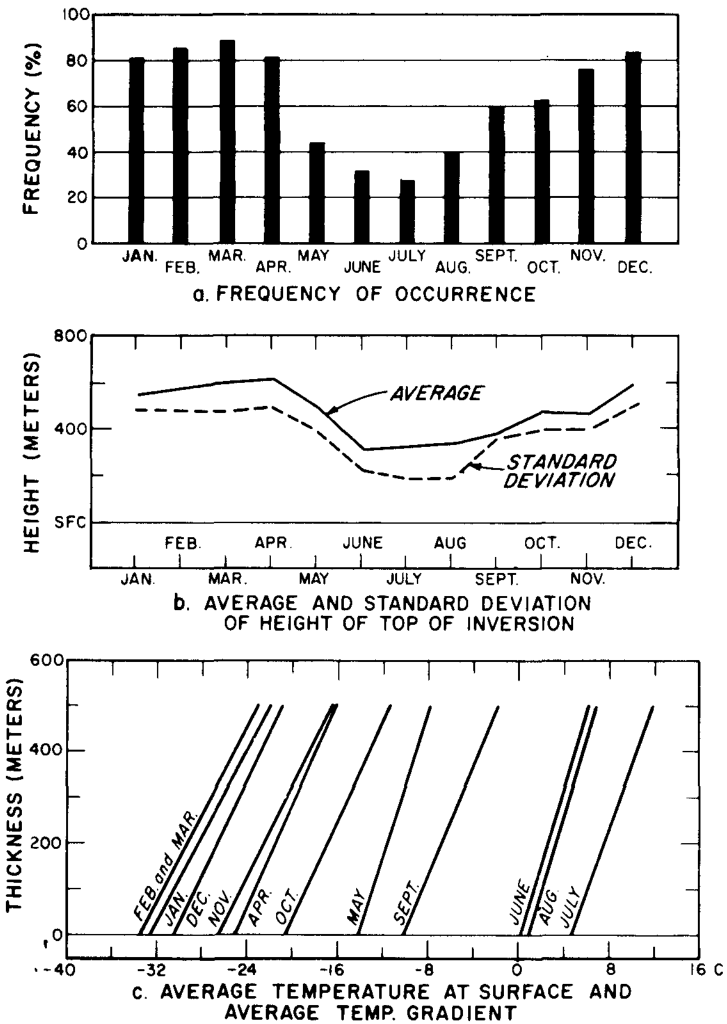


Figure 2. Statistical summary of inversions with the base at the surface, Alert, Canada.

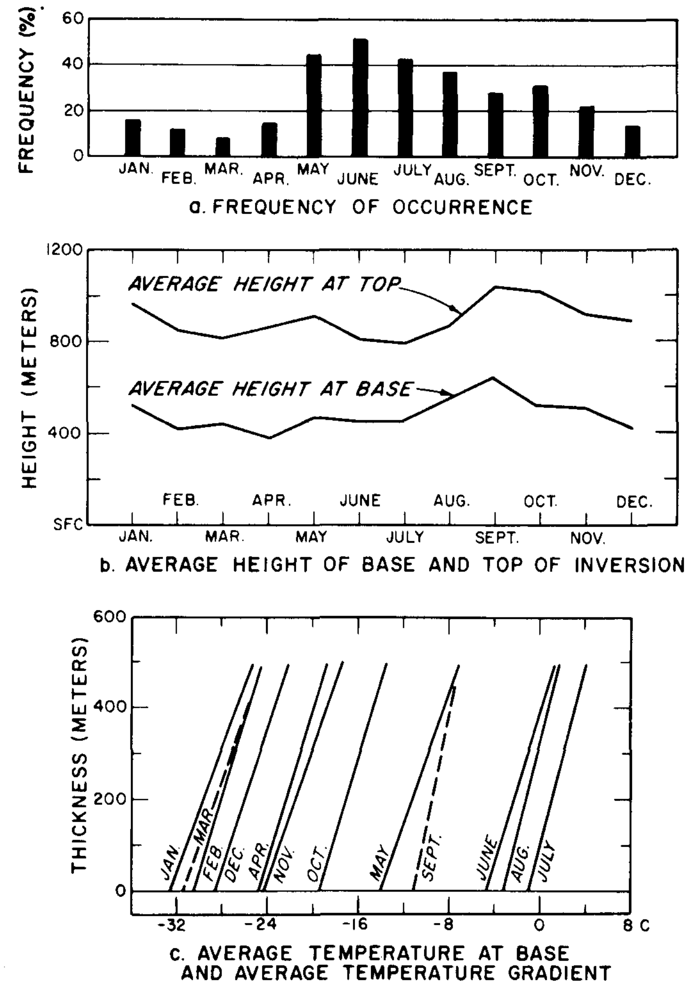


Figure 3. Statistical summary of inversions with the base above the surface, Alert, Canada.

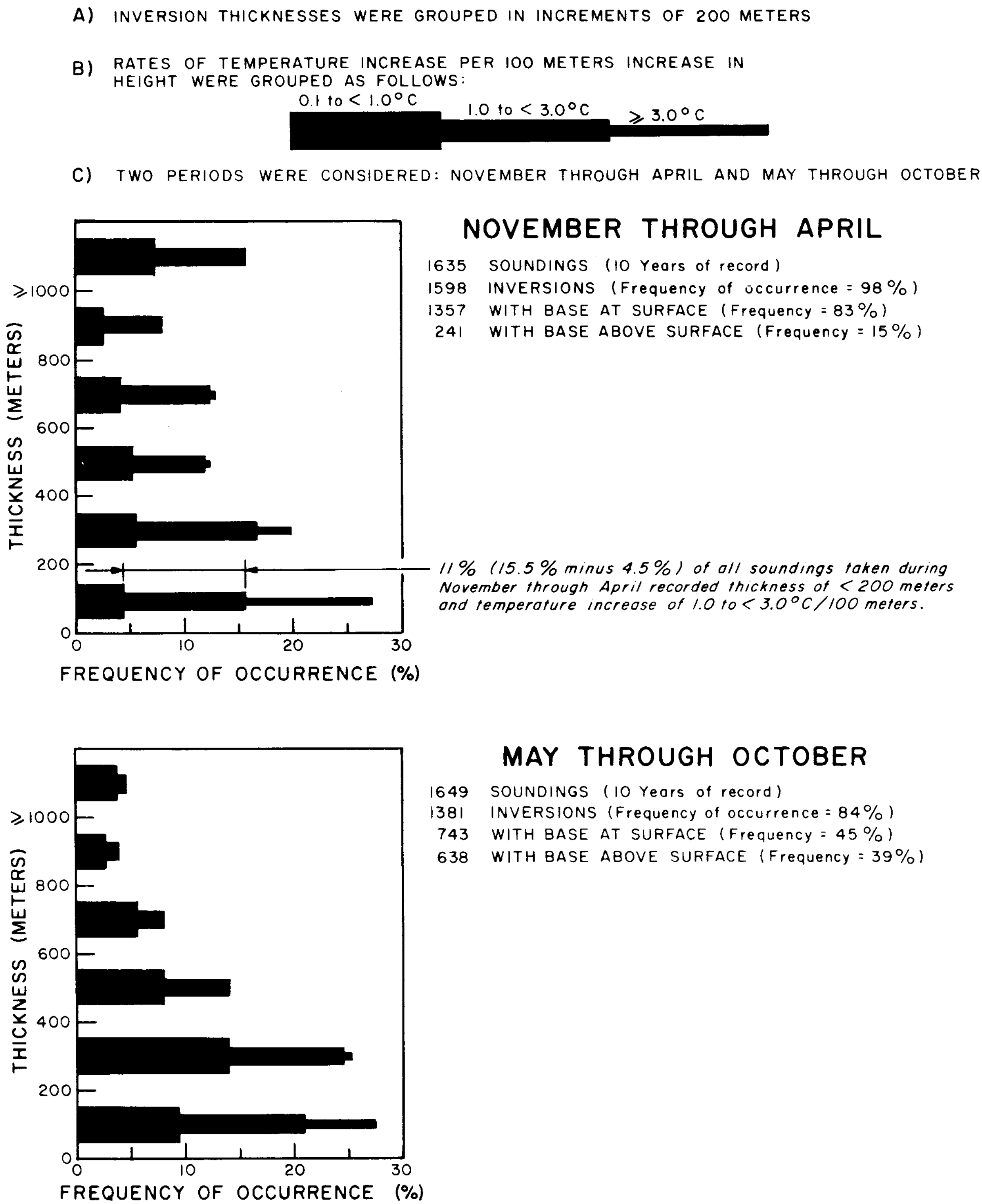


Figure 4. Frequency of inversion occurrence, in terms of thickness and temperature gradient, for two 6-month periods.

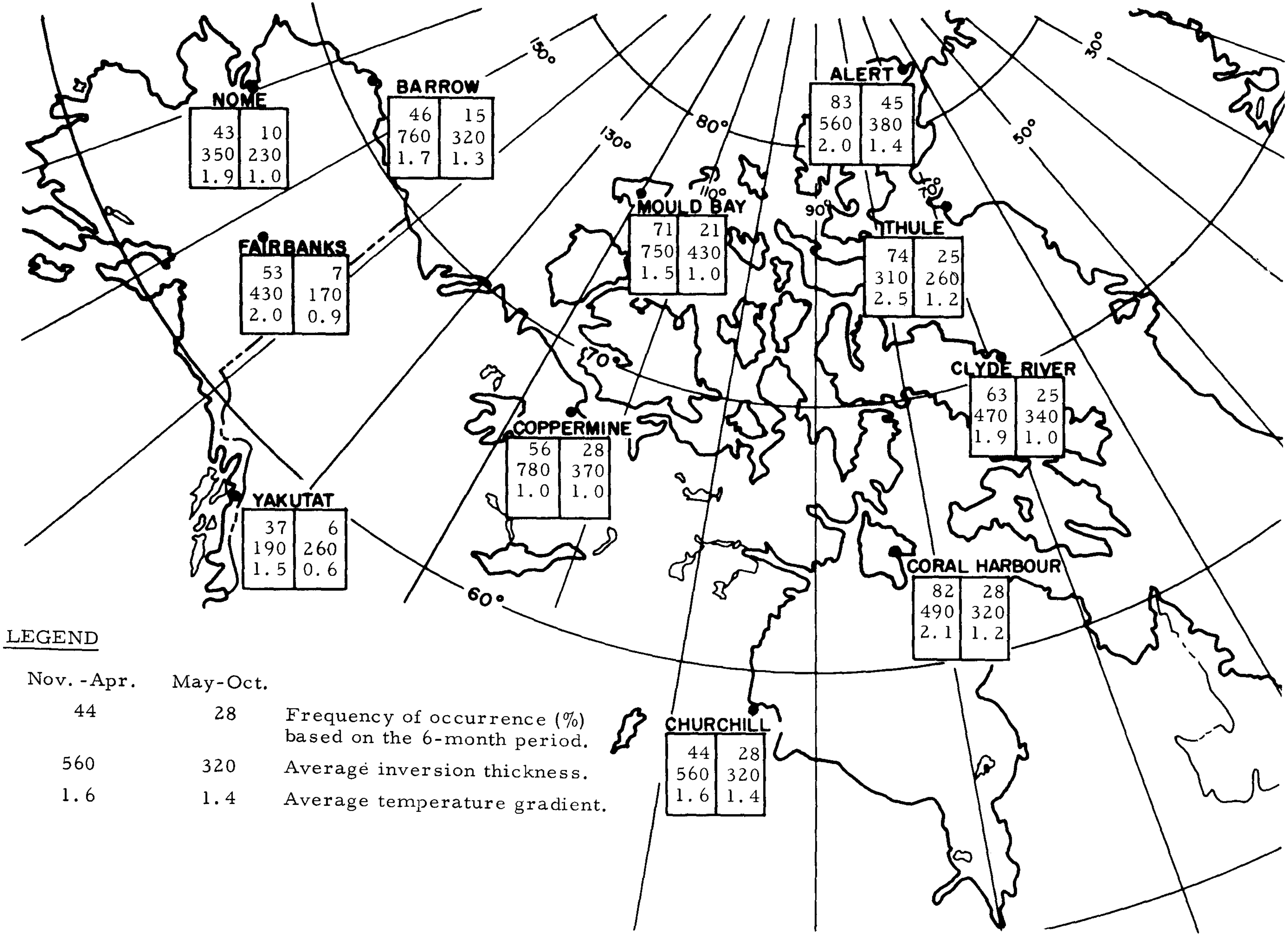


Figure 5. Inversions with base at the surface.

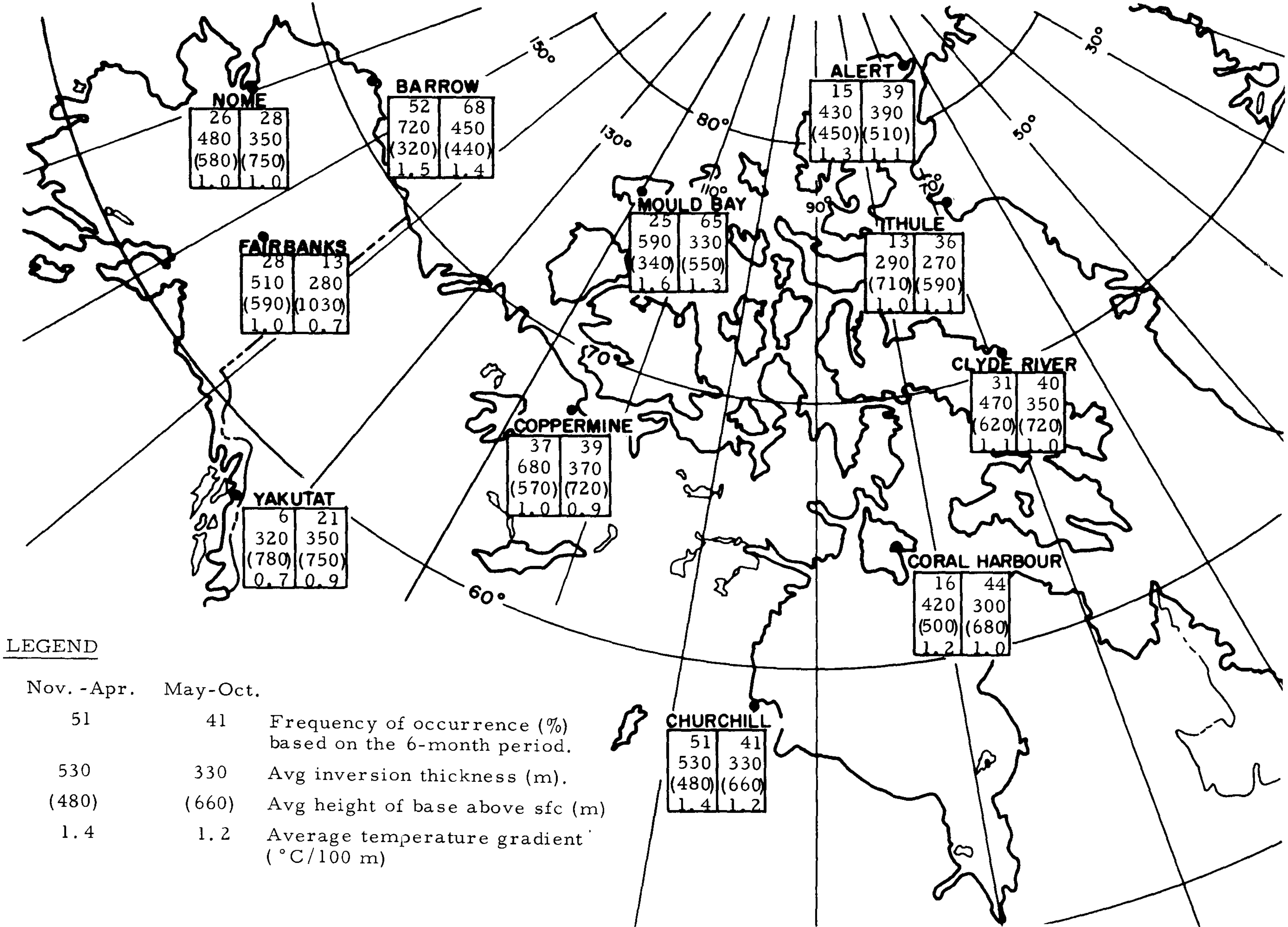
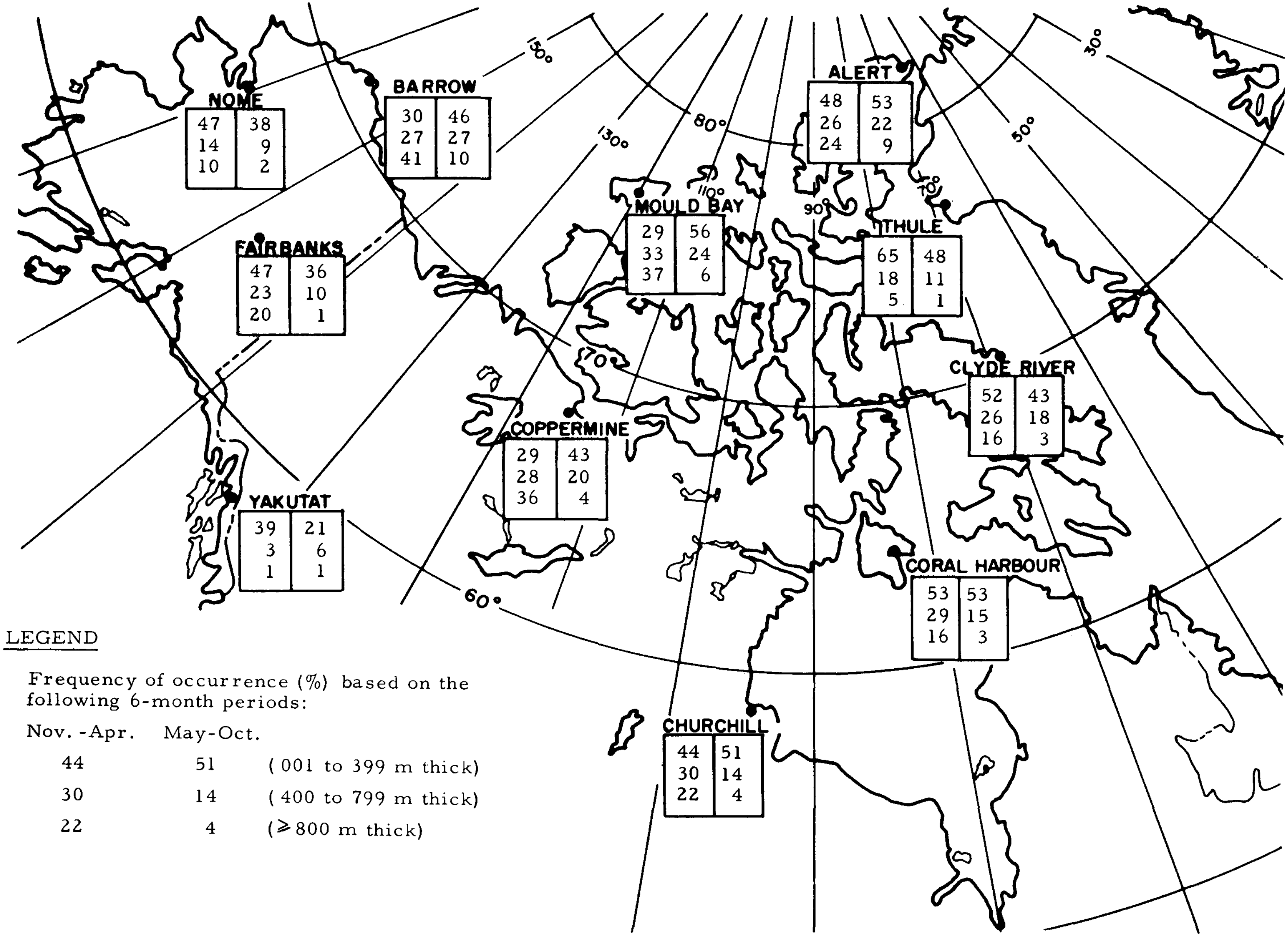


Figure 6. Inversions with base above the surface.

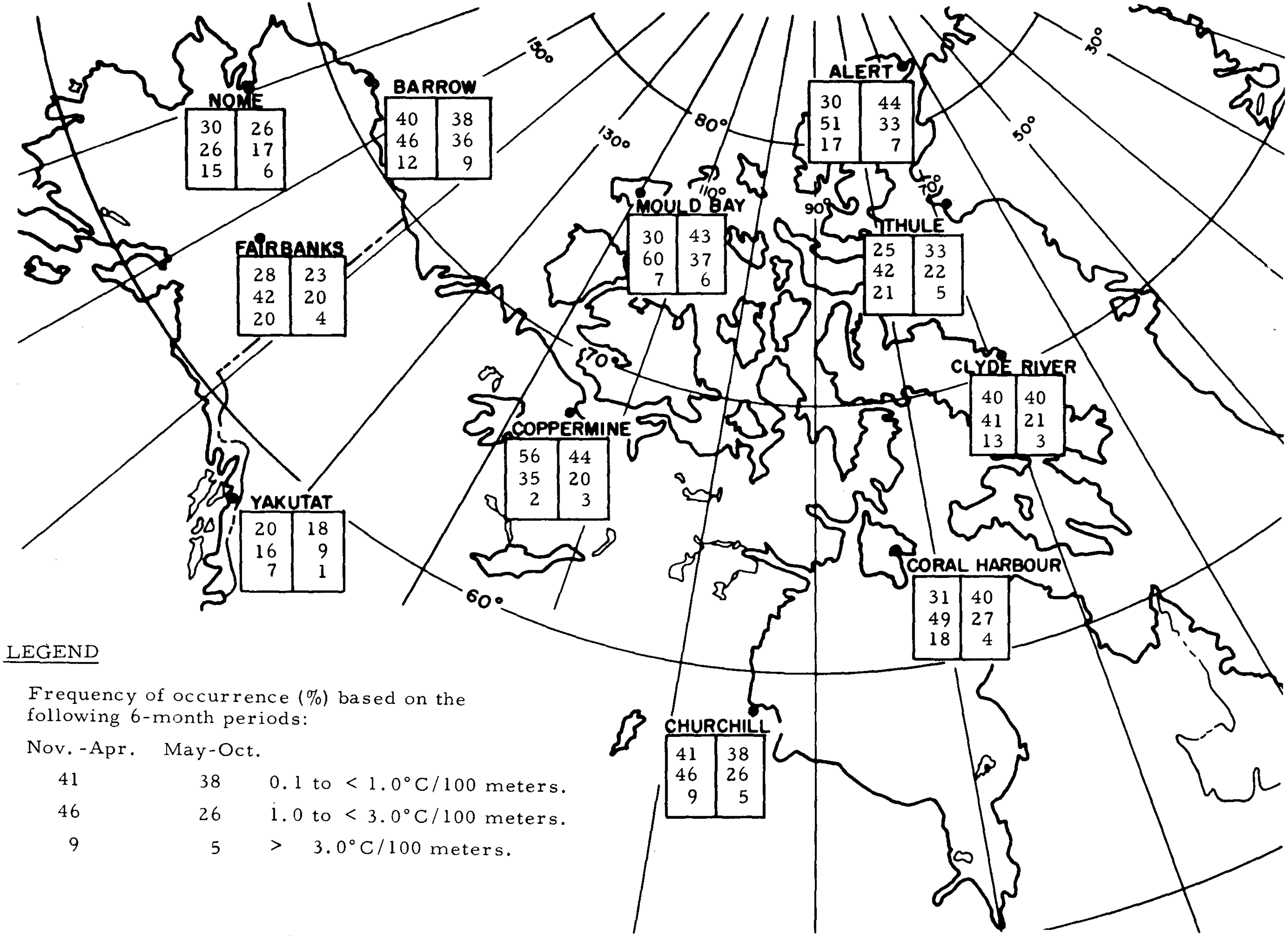


LEGEND

Frequency of occurrence (%) based on the following 6-month periods:

Nov.-Apr.	May-Oct.	
44	51	(001 to 399 m thick)
30	14	(400 to 799 m thick)
22	4	(≥800 m thick)

Figure 7. Frequency of various inversion thicknesses.



LEGEND

Frequency of occurrence (%) based on the following 6-month periods:

Nov.-Apr.	May-Oct.	
41	38	0.1 to < 1.0°C/100 meters.
46	26	1.0 to < 3.0°C/100 meters.
9	5	> 3.0°C/100 meters.

Figure 8. Frequency of various inversion temperature gradients.

During the cold months the thickness of type 1 inversions varies to some extent from place to place. During the summer months the thicknesses are regionally uniform, except at Fairbanks, where shallow surface inversions are observed.

Average temperature gradients for type 1 inversions also vary from place to place during the cold months, ranging from 1.0 to 2.5C/100m. During the warm months this variation is less marked, 0.6 to 1.4C/100m. In the study on typical Arctic inversions (App. A) it was found that extremely steep surface inversions occur on the Greenland ice sheet during the winter months. An observation made on 20 December 1949 at Station Eismitte in central Greenland, at latitude 70°N, showed a temperature increase of 29.4C in 350m.

From Figure 6 we find that, during the winter months, type 2 inversions are least common at Thule and Alert and generally increase in frequency to the south and west. Yakutat's climatic regime again makes this station an exception to the rule. During the summer months, variations in frequency of occurrence of type 2 inversions do not follow any geographical pattern.

Thicknesses of type 2 inversions, like those of type 1, vary from place to place during the cold period and in general are regionally uniform during the warm period. Some regional variation in average base heights occurs during each seasonal period. At all locations except Yakutat, average heights are greatest during the summer months, especially in interior Alaska. Examination of Table III reveals a notable phenomenon at many locations - a definite increase in base heights during September and October. This phenomenon, however, is not always consistent. At Alert, for example, it is only evident during September; and at Fairbanks, only during the 1200 Z observations (Table IIIB).

Temperature gradients of type 2 inversions show little seasonal and regional variation. The average range for all locations during both seasons is 0.7 to 1.6C/100m.

Regional variation of frequency of occurrence for three categories of inversion thickness (001 to 399 m, 400 to 799 m, and $\geq$ 800 m) is shown in Figure 7. The frequencies are obtained from Table IV. Inversions less than 400 m thick predominate during the warm months. Inversions thicker than 800 m are observed much more frequently in winter than in summer, and at some stations (Barrow, Mould Bay and Coppermine) they actually occur more often than either of the other two categories.

Figure 8 gives frequency of occurrence of three categories of inversion temperature gradients (also from Table IV). Temperature gradients of 0.1 to < 1.0C/100 m predominate during the warm months. In winter, inversions are much steeper, as indicated by the marked increase in frequencies for the categories above 1.0C/100 m.

Diurnal variations. Data on two observations per day were available for Fairbanks and Nome, Alaska, only. Nome time is 11 hours earlier, and Fairbanks is 10 hours earlier than Greenwich Meridian Time. This means that the 2400 Z observation is made at 1300 local time in Nome and at 1400 in Fairbanks, and the 1200 Z observation is made at 0100 and 0200 local time in Nome and Fairbanks respectively. These times are given to show how the release time for the upper air soundings varies from east to west. Therefore, attempts to associate diurnal variations between locations longitudinally distant from each other are not possible.

Inspection of the data for Fairbanks and Nome shows some diurnal variations with respect to seasons. For example, for type 1 inversions, frequency, height, and temperature gradient (Table IIA) show seasonal variations for the 2400 Z observation, but only temperature gradient varies (Table IIB) seasonally for the 1200 Z observation. For type 2 inversions (Table IIIA), height of base, thickness, and temperature gradient show seasonal variations for the 2400 Z observation at

Fairbanks only, whereas only thickness shows seasonal variation for the 1200 Z observation (Table IIIB) . Almost no seasonal variations are noted for type 2 inversions at Nome for either observation. This absence is probably due to maritime influence. Apparently the Pacific Ocean cools the lower atmosphere during summer and warms it during winter. This maritime effect at Nome is further indicated by the relatively narrow range in inversion base temperatures noted in column 7 of Tables IIB, IIIA, and IIIB.

On a year-round basis, type 1 inversions for both stations are more frequent and steeper (although not necessarily deeper) during the 1200 Z observation. This may be attributed to nighttime radiational heat loss.

Type 2 inversions, on an annual basis, occur only slightly more often during the 2400 Z observation than at 1200 Z; and, except for base heights at Fairbanks, few diurnal variations are found at the stations. At Fairbanks the average base height during June, July and August is almost twice as high during the day as at night.

The diurnal variations noted at these stations indicate that two observations per day are required at stations below the Arctic Circle. For the purposes of inversion studies, it would also be beneficial if these observations were made at the time of local maximum and minimum daily temperatures rather than according to Greenwich Meridian Time.

Finally, the day-to-day variations must be considered. Figure 9 is an excerpt from Wyatt's (1951) study on daily variations in Arctic inversions. The temperatures from the surface to 300 m for each day are indicated by 5C isotherms (thin lines). The heavy line connects the warmest points on the successive sounding curves and thus shows the daily variations in the height of the inversion.

The great day-to-day variation in the height of the inversion is immediately evident from these curves. Attempts to predict such variations on a day-to-day basis obviously would be difficult; therefore a statistical study such as the one given here is the next best prognostic approach.

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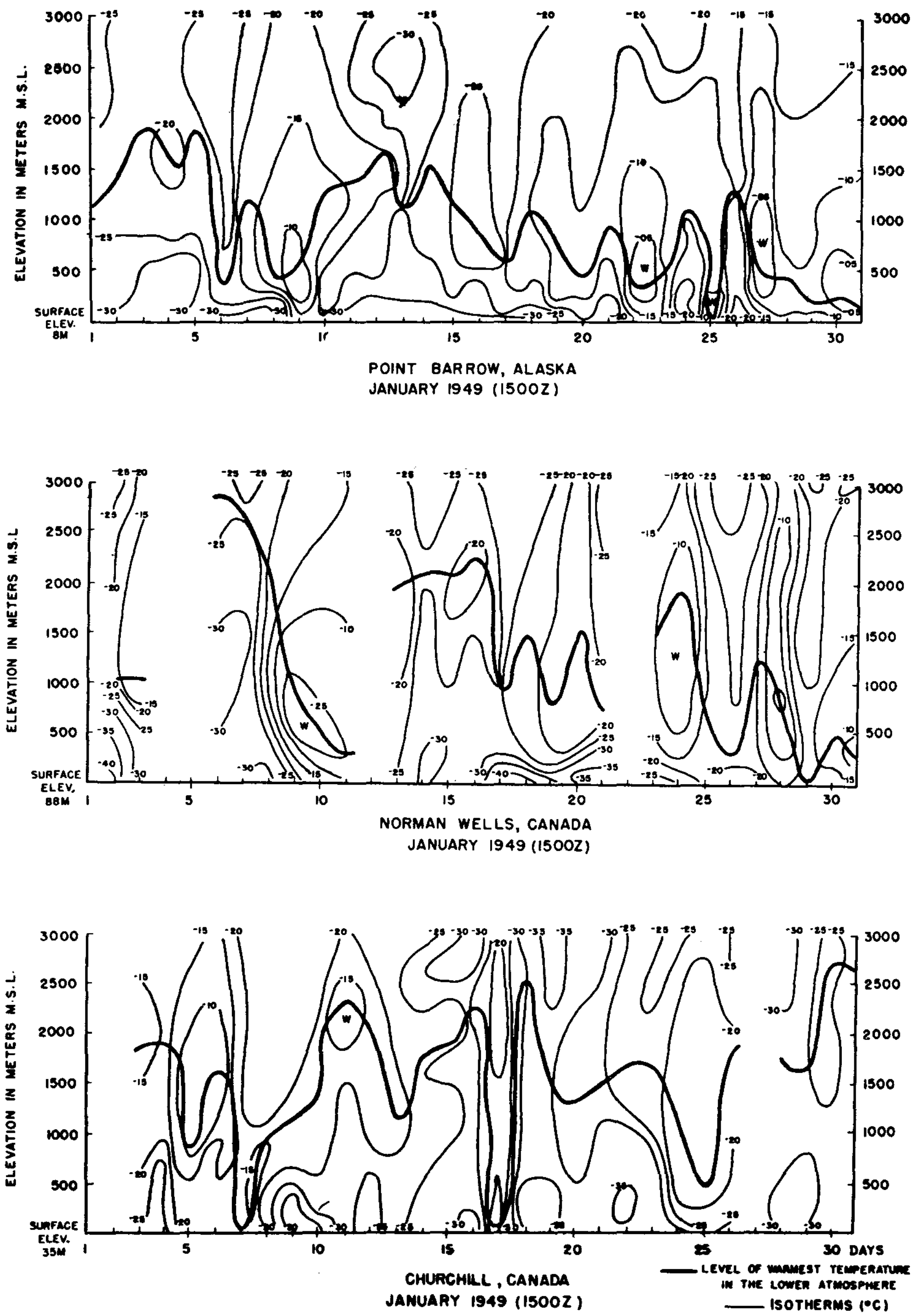

Figure 9. Day-to-day variations in height of warmest temperature in the lower atmosphere. (From W.H. Wyatt, 1951)

Table II. Statistical summary of inversions in which the base is at the surface.

1	2	3	3a*	5	5a†	6	6a†	7
Month	Number of soundings	Number of inversions (with base at sfc)	Frequency of occurrence (%)	Average thickness (m)	Standard deviation	Avg temp gradient (°C/100m)	Standard deviation	Avg temp at base (°C)
			Alert, Canada (~10-yr record)					
Jan	274	223	81	550	480	2.1	1.8	-32
Feb	251	217	86	580	440	2.1	1.8	-34
March	262	234	89	600	470	2.1	1.6	-34
April	246	200	81	610	490	1.8	1.8	-25
May	276	121	44	490	390	1.3	1.3	-14
June	247	80	32	310	220	1.2	1.1	0
July	277	78	28	310	180	1.4	1.2	+ 5
Aug	272	108	40	330	180	1.2	1.2	+ 1
Sept	275	165	60	370	360	1.7	1.7	-10
Oct	302	191	63	470	390	1.8	1.7	-21
Nov	295	224	76	460	390	2.0	1.8	-26
Dec	307	259	84	590	490	1.9	1.7	-30
			Barrow, Alaska (~8-yr record)					
Jan	216	134	62	880	600	2.0	1.6	-28
Feb	195	97	50	990	580	1.6	1.5	-30
March	187	76	41	820	450	1.4	1.2	-26
April	181	47	26	540	400	1.6	1.3	-14
May	217	4	2	290	140	0.7	0.7	- 2
June	207	25	12	350	210	1.3	0.8	+ 4
July	248	50	20	350	200	1.2	0.9	+ 6
Aug	245	32	13	280	200	0.9	0.9	+ 6
Sept	238	39	16	240	260	2.0	2.0	+ 2
Oct	248	67	27	330	310	1.9	1.7	-10
Nov	210	80	38	530	430	1.7	1.4	-22
Dec	217	123	57	790	550	1.8	1.8	-28
			Churchill, Canada (~10-yr record)					
Jan	300	155	52	690	480	1.6	1.6	-30
Feb	275	148	54	670	470	1.5	1.4	-27
March	301	157	52	520	440	1.8	1.7	-19
April	287	109	38	420	290	1.4	1.3	- 8
May	301	79	26	420	270	1.5	1.5	- 1
June	298	81	27	330	200	1.5	1.5	+ 8
July	306	108	35	310	200	1.1	0.9	+14
Aug	300	98	33	280	170	1.3	1.3	+14
Sept	289	83	29	230	140	1.2	1.1	+ 8
Oct	305	58	19	370	270	1.6	1.4	+ 2
Nov	279	72	26	410	270	1.7	1.7	-14
Dec	289	130	45	660	430	1.4	1.0	-24

* 3a is the frequency of occurrence for inversions in which the base is at the surface (column 3/column 2).

† 5a and 6a are standard deviations for the data given in columns 5 and 6, respectively.

Table II (cont'd). Statistical summary of inversions in which the base is at the surface.

1	2	3	3a*	5	5a†	6	6a†	7
Month	Number of soundings	Number of inversions (with base at sfc)	Frequency of occurrence (%)	Average thickness (m)	Standard deviation	Avg temp gradient (°C/100m)	Standard deviation	Avg temp at base (°C)
			Clyde River, Canada (~9-yr record)					
Jan	260	158	61	450	370	1.6	1.3	-29
Feb	250	174	70	470	380	2.2	1.9	-30
March	288	216	75	560	470	2.0	1.7	-28
April	287	181	63	390	320	2.2	1.8	-21
May	237	74	31	330	250	1.4	1.4	- 9
June	263	59	22	380	250	0.9	0.9	+ 3
July	254	75	30	340	190	1.0	1.0	+ 6
Aug	259	70	27	340	180	1.0	0.9	+ 5
Sept	241	41	17	340	220	0.8	0.7	- 1
Oct	267	55	21	320	190	1.1	1.1	- 8
Nov	253	117	46	410	320	1.4	1.2	-20
Dec	261	158	61	520	450	1.7	1.5	-26
			Coppermine, Canada (~10-yr record)					
Jan	296	164	55	840	590	1.1	1.1	-32
Feb	273	178	65	910	540	1.0	0.5	-33
March	272	169	62	840	510	1.0	0.7	-27
Arpil	298	141	47	630	410	0.8	0.6	-16
May	306	82	27	410	220	0.8	0.6	- 3
June	286	93	33	400	210	1.3	1.1	+ 5
July	305	92	30	380	200	1.4	1.4	+10
Aug	284	76	27	340	140	1.1	0.9	+12
Sept	269	67	25	280	140	0.8	0.7	+ 5
Oct	276	67	24	400	280	0.8	0.6	- 8
Nov	261	121	46	650	440	1.0	0.7	-22
Dec	293	182	62	790	460	1.1	0.9	-28
			Coral Harbour, Canada (~9-yr record)					
Jan	269	231	86	520	400	2.5	2.4	-31
Feb	245	210	86	520	410	2.3	2.2	-31
March	271	234	86	560	400	2.0	1.9	-25
April	257	187	73	460	330	1.7	1.7	-15
May	277	99	36	350	290	1.1	0.9	- 8
June	261	59	23	370	230	1.0	0.8	+ 3
July	265	58	22	310	150	1.0	0.8	+10
Aug	300	75	25	250	200	1.2	1.2	+ 8
Sept	228	46	20	270	190	1.0	0.9	+ 2
Oct	291	119	41	340	300	1.7	1.7	-12
Nov	290	219	76	400	270	1.9	1.7	-20
Dec	290	239	82	480	340	2.3	2.2	-27

* 3a is the frequency of occurrence for inversions in which the base is at the surface (column 3/column 2).

† 5a and 6a are standard deviations for the data given in columns 5 and 6, respectively.

Table II (Cont'd). Statistical summary of inversions in which the base is at the surface.

1	2	3	3a*	5	5a†	6	6a†	7
Month	Number of soundings	Number of inversions (with base at sfc)	Frequency of occurrence (%)	Average thickness (m)	Standard deviation	Avg temp gradient (°C/100m)	Standard deviation	Avg temp at base
			Mould Bay, Canada (~10-yr record)					
Jan	299	215	72	840	480	1.7	1.0	-35
Feb	269	221	82	800	450	1.5	0.9	-37
March	301	251	83	860	450	1.6	1.0	-33
April	260	144	55	690	350	1.2	0.8	-23
May	303	39	13	470	300	1.0	1.0	-12
June	296	24	8	430	290	0.7	0.6	+ 4
July	309	62	20	320	200	1.1	0.8	+ 6
Aug	305	48	16	410	270	0.8	0.6	+ 5
Sept	293	62	21	440	300	1.1	0.7	- 7
Oct	298	141	47	490	310	1.3	1.0	-18
Nov	293	186	63	590	360	1.5	0.9	-27
Dec	305	222	73	710	400	1.5	0.8	-32
			Thule, Greenland (~5-yr record)					
Jan	133	97	73	280	250	2.5	1.8	-25
Feb	137	103	75	340	280	2.8	2.8	-26
March	152	125	82	330	300	2.6	2.6	-26
April	148	99	67	350	320	2.2	2.1	-17
May	153	25	16	220	150	0.8	0.8	- 7
June	149	21	14	370	150	1.0	0.7	+ 4
July	155	18	12	270	110	1.2	1.2	+ 7
Aug	179	35	20	300	180	1.0	0.9	+ 5
Sept	172	56	33	200	140	1.0	0.9	- 3
Oct	169	89	53	210	170	2.2	1.8	-11
Nov	170	110	65	250	240	2.4	1.8	-20
Dec	180	150	83	290	260	2.6	2.6	-23
			Yakutat, Alaska (~9-yr record)					
Jan	276	170	62	210	160	2.1	2.1	- 3
Feb	252	101	40	210	170	1.2	1.0	- 2
March	277	42	15	160	90	0.8	0.5	+ 1
April	270	18	7	210	160	0.7	0.6	+ 5
May	270	10	4	150	60	0.4	0.4	+ 8
June	269	4	1	330	130	0.6	0.3	+14
July	277	4	1	450	170	0.5	0.3	+18
Aug	278	2	1	170	70	0.3	0.1	+14
Sept	269	15	6	270	120	0.5	0.5	+11
Oct	277	73	26	180	90	1.1	0.8	+ 5
Nov	268	118	44	180	90	2.0	1.8	0
Dec	278	154	55	190	120	2.2	2.2	- 3

* 3a is the frequency of occurrence for inversions in which the base is at the surface (column 3/column 2).

† 5a and 6a are standard deviations for the data given in columns 5 and 6, respectively.

Table IIa. Statistical summary of inversions in which the base is at the surface (2400 Z observations).

1	2	3	3a*	5	5a†	6	6a†	7
Month	Number of soundings	Number of inversions (with base at sfc)	Frequency of occurrence (%)	Average thickness (m)	Standard deviation	Avg temp gradient (°C/100m)	Standard deviation	Avg temp at base (°C)
			Fairbanks, Alaska (~9-yr record)					
Jan	277	224	81	690	500	2.6	2.3	-23
Feb	253	142	56	480	410	1.8	1.5	-17
March	279	84	30	190	180	1.3	1.3	- 6
April	240	15	6	120	50	0.8	0.6	+ 2
May	248	0	-	-	-	-	-	-
June	239	2	1	150	110	1.1	0.7	+16
July	279	4	1	180	80	0.6	0.2	+20
Aug	279	2	1	170	10	0.7	0.7	+17
Sept	270	14	5	130	60	0.7	0.5	+12
Oct	279	78	28	230	220	1.4	1.4	0
Nov	271	179	66	440	360	2.6	2.6	-14
Dec	279	230	82	680	500	2.6	2.5	-23
			Nome, Alaska (~9-yr record)					
Jan	275	164	60	430	420	2.3	2.2	-16
Feb	252	138	55	370	360	1.9	1.9	-16
March	276	76	28	380	340	1.0	1.0	-13
April	270	36	13	340	330	0.8	0.8	- 1
May	279	44	16	190	110	1.5	1.5	+ 5
June	267	45	17	250	170	1.3	1.3	+10
July	310	27	9	300	230	1.3	1.3	+13
Aug	310	6	2	400	180	0.4	0.4	+15
Sept	300	5	2	120	60	0.4	0.3	+ 7
Oct	310	38	12	140	60	1.0	1.0	- 2
Nov	297	127	43	240	230	1.9	1.9	-10
Dec	308	186	60	330	320	3.3	3.3	-19

Table IIb. Statistical summary of inversions in which the base is at the surface (1200 Z observations).

			Fairbanks, Alaska (~9-yr record)					
Jan	277	232	84	640	480	3.4	3.2	-25
Feb	254	210	83	560	460	3.0	2.8	-22
March	279	239	86	420	340	3.0	2.9	-18
April	239	191	80	310	250	1.9	1.7	- 5
May	248	179	72	240	140	1.5	1.5	+ 5
June	239	149	62	280	130	1.4	1.2	+11
July	280	173	62	320	170	1.3	1.1	+11
Aug	278	193	69	310	140	1.3	1.0	+ 9
Sept	269	191	71	290	160	1.5	1.4	+ 3
Oct	279	186	67	350	280	2.1	2.0	- 7
Nov	272	211	78	500	410	2.7	2.6	-16
Dec	278	229	82	610	490	3.2	3.2	-24

* 3a is the frequency of occurrence for inversions in which the base is at the surface (column 3/column 2).
† 5a and 6a are standard deviations for the data given in columns 5 and 6, respectively.

Table IIb (Cont'd). Statistical summary of inversions in which the base is at the surface (1200 Z observations).

1	2	3	3a*	5	5a†	6	6a†	7
Month	Number of soundings	Number of inversions (with base at sfc)	Frequency of occurrence (%)	Average thickness (m)	Standard deviation	Avg temp gradient (°C/100m)	Standard deviation	Avg temp at base (°C)
			Nome, Alaska (~9-yr record)					
Jan	275	161	59	450	440	2.7	2.7	-18
Feb	253	164	65	380	360	2.8	2.8	-18
March	275	169	61	410	400	3.0	3.0	-17
April	269	165	61	320	300	2.9	2.9	-10
May	278	161	58	220	130	2.0	1.8	+ 2
June	269	138	51	280	210	1.8	1.5	+ 7
July	310	126	41	300	220	1.7	1.4	+ 8
Aug	310	116	37	200	140	1.8	1.4	+ 8
Sept	300	128	43	180	130	2.1	2.1	+ 3
Oct	309	150	49	170	140	2.3	2.3	- 4
Nov	296	146	49	200	170	2.4	2.4	-10
Dec	308	184	60	340	330	3.3	3.3	-19

* 3a is the frequency of occurrence for inversions in which the base is at the surface (column 3/column 2).
† 5a and 6a are standard deviations for the data given in columns 5 and 6, respectively.

Table III. Statistical summary of inversions in which the base is above the surface.

1	2	3	3a*	4	4a†	5	5a†	6	6a†	7
Month	Number of soundings	Number of inversions (with base above sfc)	Frequency of occurrence (%)	Avg height of base above sfc (m)	Standard deviation	Average thickness (m)	Standard deviation	Avg temp gradient (°C/100 m)	Standard deviation	Avg temp at base (°C)
				Alert, Canada (~10-yr record)						
Jan	274	44	16	520	350	440	350	1.4	1.1	-32
Feb	251	29	12	420	300	430	310	1.2	0.9	-30
March	262	22	8	440	250	370	250	1.4	0.8	-31
April	246	38	15	380	250	480	440	1.2	0.9	-25
May	276	123	45	470	360	440	300	1.4	1.4	-14
June	247	125	51	450	340	360	230	1.2	1.2	- 5
July	277	120	43	450	340	340	200	1.0	1.0	- 1
Aug	272	101	37	550	360	320	270	1.0	1.0	- 3
Sept	275	76	28	640	410	400	290	0.8	0.6	-11
Oct	302	93	31	520	310	500	400	1.2	1.2	-20
Nov	295	65	22	510	290	410	320	1.4	1.2	-24
Dec	307	43	14	420	210	470	370	1.3	1.0	-29
				Barrow, Alaska (~8-yr record)						
Jan	216	73	34	340	250	780	450	1.4	1.1	-26
Feb	195	95	49	290	180	870	550	1.5	1.2	-30
March	187	108	58	230	150	840	430	1.5	1.2	-27
April	181	126	70	300	250	660	420	1.5	1.4	-18
May	217	206	95	420	230	550	350	1.5	1.2	-10
June	207	161	78	340	220	480	260	1.7	1.3	- 2
July	248	157	63	310	300	480	310	1.5	1.5	+ 1
Aug	245	156	64	400	260	430	260	1.2	1.1	0
Sept	238	134	56	590	330	380	230	1.1	1.1	- 5
Oct	248	133	54	580	350	390	260	1.4	1.2	-14
Nov	210	127	60	400	250	560	410	1.6	1.3	-20
Dec	217	90	41	330	210	640	420	1.6	1.6	-25

* 3a is the frequency of occurrence for inversions in which the base is above the surface (column 3/column 2).
† 4a, 5a and 6a are standard deviations for the data given in columns 4, 5 and 6, respectively.

Table III (Cont'd). Statistical summary of inversions in which the base is above the surface.

1	2	3	3a*	4	4a†	5	5a†	6	6a†	7
Month	Number of soundings	Number of inversions (with base above sfc)	Frequency of occurrence (%)	Avg height of base above sfc (m)	Standard deviation	Average thickness (m)	Standard deviation	Avg temp gradient (°C/100 m)	Standard deviation	Avg temp at base (°C)
				Churchill, Canada (~10-yr record)						
Jan	300	139	46	450	230	590	380	1.5	1.3	-30
Feb	275	121	44	450	240	660	430	1.4	1.0	-28
March	301	134	45	410	230	560	370	1.3	1.0	-22
April	287	167	58	450	250	440	290	1.2	1.1	-13
May	301	190	63	580	330	370	270	1.4	1.4	- 7
June	298	135	45	580	420	340	240	1.2	1.0	- 1
July	306	62	20	440	370	310	180	1.1	0.9	+ 7
Aug	300	78	26	690	470	310	230	1.0	1.0	+ 5
Sept	289	106	37	890	440	320	250	1.1	1.1	- 1
Oct	305	166	54	810	360	330	240	1.1	1.1	- 7
Nov	279	174	62	640	370	380	330	1.4	1.2	-15
Dec	289	152	53	470	280	540	430	1.6	1.1	-23
				Clyde River, Canada (~9-yr record)						
Jan	260	82	32	630	320	520	400	1.0	0.7	-27
Feb	250	67	27	550	260	500	360	1.0	0.7	-28
March	288	64	22	570	370	490	280	1.1	0.8	-24
April	287	90	31	660	320	450	310	1.0	0.8	-19
May	237	115	49	680	350	400	250	1.0	0.7	-10
June	263	130	49	590	390	370	250	0.9	0.7	- 3
July	254	113	44	490	350	320	220	1.1	1.1	0
Aug	259	103	40	640	380	350	220	0.8	0.7	- 1
Sept	241	63	26	960	380	340	220	0.9	0.8	- 7
Oct	267	79	30	940	340	320	240	1.2	1.2	-14
Nov	253	111	44	680	310	380	260	1.0	0.8	-20
Dec	261	84	32	600	320	470	310	1.2	1.1	-24
				Coppermine, Canada (~10-yr record)						
Jan	296	107	36	610	310	690	430	1.0	0.7	-30
Feb	273	83	30	590	300	890	580	0.9	0.5	-31
March	272	91	33	460	220	740	390	1.1	0.6	-25
April	298	130	44	510	300	580	410	0.9	0.7	-19
May	306	173	57	620	330	440	310	0.8	0.6	- 9
June	286	110	38	680	440	360	240	1.2	1.2	- 3
July	305	96	31	680	420	370	210	0.9	0.9	+ 4
Aug	284	77	27	640	440	330	170	0.8	0.8	+ 4
Sept	269	91	34	880	360	310	150	0.7	0.6	- 3
Oct	276	126	46	840	340	380	260	0.8	0.7	-12
Nov	261	117	45	640	360	530	300	1.0	0.8	-21
Dec	293	92	31	610	310	620	410	1.1	0.9	-26

* 3a is the frequency of occurrence for inversions in which the base is above the surface (column 3/column 2).

† 4a, 5a and 6a are standard deviations for the data given in columns 4, 5 and 6, respectively.

Table III (Cont'd). Statistical summary of inversions in which the base is above the surface.

1	2	3	3a*	4	4a†	5	5a†	6	6a†	7
Month	Number of soundings	Number of inversions (with base above sfc)	Frequency of occurrence (%)	Avg height of base above sfc (m)	Standard deviation	Average thickness (m)	Standard deviation	Avg temp gradient (°C/100 m)	Standard deviation	Avg temp at base (°C)
				Coral Harbour, Canada (~9-yr record)						
Jan	269	37	14	380	210	510	430	1.2	1.0	-24
Feb	245	32	13	440	230	480	310	1.2	0.6	-28
March	271	35	13	490	310	420	290	1.3	1.0	-20
April	257	64	25	510	270	390	280	1.1	0.8	-16
May	277	159	57	620	330	330	210	1.2	1.0	- 8
June	261	133	51	700	370	330	230	1.1	0.8	- 3
July	265	93	35	620	410	300	200	0.8	0.8	+ 5
Aug	300	99	33	680	420	260	160	0.9	0.7	+ 3
Sept	228	102	45	760	370	270	160	1.0	0.9	- 4
Oct	291	116	40	720	370	280	210	1.3	0.9	-11
Nov	290	57	20	640	370	310	200	1.4	1.0	-16
Dec	290	38	13	550	310	420	290	1.3	1.3	-20
				Mould Bay, Canada (~10-yr record)						
Jan	299	74	25	310	250	620	400	1.6	1.1	-31
Feb	269	44	16	350	190	660	420	1.5	1.4	-33
March	301	44	15	290	190	690	370	1.5	0.9	-29
April	260	102	39	340	290	540	350	1.5	1.3	-22
May	303	241	80	540	330	370	250	1.6	1.6	-14
June	296	215	73	630	320	300	220	1.3	1.2	- 4
July	309	168	54	600	310	300	200	1.0	0.8	0
Aug	305	199	65	570	340	330	230	1.3	1.3	- 2
Sept	293	203	69	500	300	340	210	1.1	0.8	- 8
Oct	298	141	47	450	320	340	220	1.6	1.1	-18
Nov	293	97	33	350	210	480	330	1.6	1.2	-26
Dec	305	73	24	410	250	550	350	1.6	1.0	-28
				Thule, Greenland (~5-yr record)						
Jan	133	19	14	800	460	270	260	0.8	0.8	-22
Feb	137	22	16	600	420	250	130	1.4	1.3	-24
March	152	14	9	610	450	300	200	1.4	1.1	-24
April	148	27	18	750	460	340	310	0.7	0.3	-19
May	153	65	42	640	460	260	180	0.9	0.9	- 9
June	149	71	48	390	430	320	210	1.2	1.2	- 1
July	155	84	54	280	270	250	140	1.2	1.1	+ 3
Aug	179	70	39	640	530	300	200	0.9	0.9	0
Sept	172	28	16	760	450	270	160	0.9	0.9	- 5
Oct	169	25	15	840	510	200	170	1.3	1.1	-12
Nov	170	27	16	730	390	270	170	1.2	1.2	-17
Dec	180	12	7	760	400	320	280	0.6	0.4	-24

* 3a is the frequency of occurrence for inversions in which the base is above the surface (column 3/column 2).

† 4a, 5a, and 6a are standard deviations for the data given in columns 4, 5, and 6, respectively.

Table III (Cont'd). Statistical summary of inversions in which the base is above the surface.

1 Month	2 Number of soundings	3 Number of inversions (with base above sfc)	3a* Frequency of occurrence (%)	4 Avg height of base above sfc (m)	4a† Standard deviation	5 Average thickness (m)	5a† Standard deviation	6 Avg temp gradient (°C/100 m)	6a† Standard deviation	7 Avg temp at base (°C)
				Yakutat, Alaska (~9-yr record)						
Jan	276	15	5	480	360	310	300	1.0	0.8	- 7
Feb	252	22	9	860	410	260	150	0.6	0.6	- 5
March	277	13	5	1060	450	370	230	1.0	0.7	- 6
April	270	28	10	860	440	390	270	0.6	0.5	- 2
May	270	45	17	770	500	310	210	1.0	1.0	+ 3
June	269	89	33	670	410	340	220	1.2	0.9	+ 7
July	277	84	30	780	430	390	220	0.9	0.8	+ 8
Aug	278	66	24	680	450	380	240	0.9	0.6	+10
Sept	269	34	13	800	420	390	350	0.7	0.7	+ 6
Oct	277	25	9	790	470	280	180	0.6	0.5	+ 3
Nov	268	11	4	820	400	430	280	0.4	0.4	- 1
Dec	278	7	3	580	570	190	80	0.6	0.5	- 2

Table IIIa. Statistical summary of inversions in which the base is above the surface (2400 Z observations).

Month	2	3	3a*	4	4a†	5	5a†	6	6a†	7
				Fairbanks, Alaska (~9-yr record)						
Jan	277	42	15	410	330	670	450	1.3	0.9	-19
Feb	253	95	38	540	360	520	340	1.1	0.8	-18
March	279	127	46	720	370	390	350	0.9	0.8	-16
April	240	57	24	980	340	290	180	0.8	0.8	-10
May	248	8	3	1120	400	270	220	0.5	0.4	0
June	239	2	1	1100	330	110	20	1.1	0.8	+ 8
July	279	4	1	1100	280	220	120	0.8	0.8	+ 8
Aug	279	7	3	1220	140	370	200	0.4	0.4	+ 5
Sept	270	39	14	880	390	290	200	0.6	0.6	+ 1
Oct	279	121	43	740	370	410	260	0.8	0.6	- 7
Nov	271	78	29	500	350	530	400	1.1	0.8	-15
Dec	279	44	16	370	280	650	410	1.3	0.7	-23
				Nome, Alaska (~9-yr record)						
Jan	275	39	14	570	290	590	500	1.0	0.8	-15
Feb	252	56	22	550	310	570	370	0.9	0.8	-14
March	276	102	37	470	320	530	350	0.9	0.9	-15
April	270	113	42	540	370	420	270	0.8	0.7	- 9
May	279	66	24	700	450	350	220	0.8	0.7	- 3
June	267	77	29	510	410	390	290	1.4	1.4	+ 4
July	310	122	39	520	380	370	290	1.3	1.3	+ 6
Aug	310	82	26	800	390	330	230	0.9	0.9	+ 5
Sept	300	53	18	1010	340	330	190	0.7	0.7	- 1
Oct	310	92	30	950	350	350	240	0.7	0.7	- 6
Nov	297	67	23	660	280	390	270	1.0	1.0	-10
Dec	308	52	17	660	360	390	320	1.2	1.0	-15

* 3a is the frequency of occurrence for inversions in which the base is above the surface (column 3/column 2).

† 4a, 5a and 6a are standard deviations for the data given in columns 4, 5 and 6, respectively.

Table IIIb. Statistical summary of inversions in which the base is above the survace (1200 Z observations).

1	2	3	3a*	4	4a†	5	5a†	6	6a†	7
Month	Number of soundings	Number of inversions (with base above sfc)	Frequency of occurrence (%)	Avg height of base above sfc (m)	Standard deviation	Average thickness (m)	Standard deviation	Avg temp gradient (°C/100 m)	Standard deviation	Avg temp at base (°C)
				Fairbanks, Alaska (~9-yr record)						
Jan	277	38	14	410	310	720	470	1.2	0.8	-21
Feb	254	38	15	440	280	630	440	1.2	0.8	-20
March	279	32	11	570	390	410	240	0.7	0.5	-16
April	239	28	12	680	410	450	320	0.6	0.5	-11
May	248	27	11	660	440	250	190	0.9	0.8	+ 1
June	239	19	8	390	320	230	100	0.8	0.6	+ 9
July	280	21	8	280	270	240	160	1.3	0.8	+10
Aug	278	15	5	400	390	200	110	1.0	0.8	+ 8
Sept	269	22	8	850	460	270	170	0.7	0.5	- 1
Oct	279	54	19	740	360	330	210	1.0	1.0	- 8
Nov	272	55	20	520	370	550	400	1.2	1.2	-17
Dec	278	42	15	370	290	720	530	1.3	0.7	-21
				Nome, Alaska (~9-yr record)						
Jan	275	43	16	560	330	540	470	1.2	1.2	-13
Feb	253	33	13	570	330	420	280	1.2	1.2	-14
March	275	34	12	560	300	330	180	1.1	0.7	-14
April	269	26	10	540	300	330	260	0.8	0.8	- 8
May	278	28	10	690	300	380	260	1.1	1.1	- 5
June	269	47	17	570	380	390	240	1.4	1.2	+ 1
July	310	79	25	640	300	450	250	0.9	0.7	+ 4
Aug	310	51	16	830	370	460	280	0.7	0.7	+ 4
Sept	300	28	9	1000	290	310	240	0.9	0.8	- 2
Oct	309	44	14	920	400	360	260	0.7	0.6	- 6
Nov	296	58	20	720	360	390	260	1.0	0.8	-10
Dec	308	45	15	670	350	460	310	1.0	0.7	-15

* 3a is the frequency of occurrence for inversions in which the base is above the surface (column 3/column 2).

† 4a, 5a and 6a are standard deviations for the data given in columns 4, 5 and 6, respectively.

Table IV. Frequency of inversion occurrence, in terms of thickness and temperature gradient, for two 6-month periods.

Alert, Canada

November through April:

1635 soundings (approximately 10 years of record).
1598 inversions observed (frequency = 97.7%) of which 1357 were with base at the surface, and 241 were with base above the surface.

	Temperature gradient (°C/100 m)					
	0.1 to < 1.0°		1.0 to < 3.0°		≥ 3.0°	
Thickness (m)	Number of inversions observed	Frequency of occurrence (%)	Number of inversions observed	Frequency of occurrence (%)	Number of inversions observed	Frequency of occurrence (%)
001-199	76	4.6	179	10.9	199	12.2
200-399	95	5.8	181	11.1	55	3.4
400-599	88	5.4	110	6.7	10	0.6
600-799	69	4.2	138	8.4	5	0.3
800-999	44	2.7	90	5.5	0	—
≥ 1000	122	7.5	137	8.4	0	—

Table IV (Cont'd). Frequency of inversion occurrence, in terms of thickness and temperature gradient, for two 6-month periods.

Alert, Canada (Cont'd)

May through October:

1649 soundings (approximately 10 years of record).
1381 inversions observed (frequency = 83.7 %) of which 743 were with base at the surface, and 638 were with base above the surface.

	Temperature gradient (°C/100 m)					
	0.1 to < 1.0°		1.0 to < 3.0°		≥ 3.0°	
Thickness (m)	Number of inversions observed	Frequency of occurrence (%)	Number of inversions observed	Frequency of occurrence (%)	Number of inversions observed	Frequency of occurrence (%)
001-199	155	9.4	193	11.7	108	6.5
200-399	231	14.0	174	10.6	12	0.7
400-599	135	8.2	96	5.8	2	0.1
600-799	92	5.6	41	2.5	0	-
800-999	44	2.7	22	1.3	0	-
≥ 1000	62	3.8	14	0.8	0	-

Barrow, Alaska

November through April:

1206 soundings (approximately 8 years of record).
1176 inversions observed (frequency = 97.5%) of which 557 were with base at the surface, and 619 were with base above the surface.

	Temperature gradient (°C/100 m)					
	0.1 to < 1.0°		1.0 to < 3.0°		≥ 3.0°	
Thickness (m)	Number of inversions observed	Frequency of occurrence (%)	Number of inversions observed	Frequency of occurrence (%)	Number of inversions observed	Frequency of occurrence (%)
001-199	36	3.0	66	5.5	68	5.6
200-399	35	2.9	109	9.0	48	4.0
400-599	39	3.2	122	10.1	23	1.9
600-799	40	3.3	103	8.5	1	0.1
800-999	61	5.1	61	5.1	0	-
≥ 1000	266	22.1	98	8.1	0	-

May through October:

1403 soundings (approximately 8 years of record).
1164 inversions observed (frequency = 83.0%) of which 217 were with base at the surface, and 947 were with base above the surface.

001-199	52	3.7	110	7.9	77	5.5
200-399	149	10.6	209	14.9	53	3.8
400-599	118	8.4	133	9.5	2	0.1
600-799	80	5.7	48	3.4	0	-
800-999	66	4.7	4	0.3	0	-
≥ 1000	60	4.3	3	0.2	0	-

Churchill, Canada

November through April:

1731 soundings (approximately 10 years of record).
1658 inversions observed (frequency = 95.8%) of which 771 were with base at the surface, and 887 were with base above the surface.

	Temperature gradient (°C/100 m)					
	0.1 to < 1.0°		1.0 to < 3.0°		≥ 3.0°	
Thickness (m)	Number of inversions observed	Frequency of occurrence (%)	Number of inversions observed	Frequency of occurrence (%)	Number of inversions observed	Frequency of occurrence (%)
001-199	85	4.9	152	8.8	109	6.2
200-399	133	7.7	232	13.4	45	2.6
400-599	114	6.6	207	12.0	6	0.3
600-799	99	5.7	100	5.8	0	-
800-999	84	4.8	54	3.1	0	-
≥ 1000	192	11.1	46	2.7	0	-

Table IV (Cont'd). Frequency of inversion occurrence, in terms of thickness and temperature gradient, for two 6-month periods.

Churchill, Canada (Cont'd)

May through October:

1799 soundings (approximately 10 years of record).
1244 inversions observed (frequency = 69.1%) of which 507 were with base at the surface, and 737 were with base above the surface.

	Temperature gradient (°C/100 m)					
	0.1 to < 1.0°		1.0 to < 3.0°		≥ 3.0°	
Thickness (m)	Number of inversions observed	Frequency of occurrence (%)	Number of inversions observed	Frequency of occurrence (%)	Number of inversions observed	Frequency of occurrence (%)
001-199	152	8.5	203	11.3	60	3.3
200-399	297	16.5	171	9.5	32	1.8
400-599	124	6.9	66	3.7	2	0.1
600-799	53	2.9	18	1.0	0	-
800-999	34	1.9	4	0.2	0	-
≥ 1000	26	1.4	2	0.1	0	-

Clyde River, Canada

November through April:

1599 soundings (approximately 9 years of record).
1502 inversions observed (frequency = 93.9%) of which 1004 were with base at the surface, and 498 were with base above the surface.

	Temperature gradient (°C/100 m)					
	0.1 to < 1.0°		1.0 to < 3.0°		≥ 3.0°	
Thickness (m)	Number of inversions observed	Frequency of occurrence (%)	Number of inversions observed	Frequency of occurrence (%)	Number of inversions observed	Frequency of occurrence (%)
001-199	95	5.9	176	11.0	166	10.4
200-399	157	9.8	204	12.8	33	2.1
400-599	127	7.9	110	6.9	9	0.6
600-799	95	5.9	78	4.9	0	-
800-999	55	3.4	45	2.8	0	-
≥ 1000	115	7.2	37	2.3	0	-

May through October:

1521 soundings (approximately 9 years of record).
977 inversions observed (frequency 64.2%) of which 374 were with base at the surface, and 603 were with base above the surface.

001-199	137	9.0	121	8.0	38	2.5
200-399	206	13.5	149	9.8	4	0.3
400-599	159	10.4	39	2.6	0	-
600-799	63	4.1	10	0.7	0	-
800-999	36	2.4	2	0.1	0	-
≥ 1000	13	0.8	0	-	0	-

Coppermine, Canada

November through April:

1693 soundings (approximately 10 years of record).
1575 inversions observed (frequency = 93.0%) of which 955 were with base at the surface, and 620 were with base above the surface.

	Temperature gradient (°C/100 m)					
	0.1 to < 1.0°		1.0 to < 3.0°		≥ 3.0°	
Thickness (m)	Number of inversions observed	Frequency of occurrence (%)	Number of inversions observed	Frequency of occurrence (%)	Number of inversions observed	Frequency of occurrence (%)
001-199	46	2.7	55	3.3	17	1.0
200-399	197	11.6	167	9.9	7	0.4
400-599	148	8.7	107	6.3	4	0.2
600-799	108	6.4	107	6.3	0	-
800-999	117	6.9	81	4.8	0	-
≥ 1000	330	19.5	84	5.0	0	-

Table IV (Cont'd). Frequency of inversion occurrence, in terms of thickness and temperature gradient, for two 6-month periods.

Coppermine, Canada (Cont'd)

May through October:

1726 soundings (approximately 10 years of record).
1150 inversions observed (frequency = 66.6%) of which 477 were with base at the surface, and 673 were with base above the surface.

	Temperature gradient (°C/100 m)					
	0.1 to < 1.0°		1.0 to < 3.0°		≥ 3.0°	
Thickness (m)	Number of inversions observed	Frequency of occurrence (%)	Number of inversions observed	Frequency of occurrence (%)	Number of inversions observed	Frequency of occurrence (%)
001-199	125	7.2	102	5.9	17	1.0
200-399	310	17.9	160	9.3	24	1.4
400-599	186	10.8	76	4.4	2	0.1
600-799	76	4.4	10	0.6	2	0.1
800-999	31	1.8	2	0.1	0	-
≥ 1000	26	1.5	1	0.1	0	-

Coral Harbour, Canada

November through April:

1622 soundings (approximately 9 years of record).
1583 inversions observed (frequency = 97.6%) of which 1320 were with base at the surface, and 263 were with base above the surface.

	Temperature gradient (°C/100 m)					
	0.1 to < 1.0°		1.0 to < 3.0°		≥ 3.0°	
Thickness (m)	Number of inversions observed	Frequency of occurrence (%)	Number of inversions observed	Frequency of occurrence (%)	Number of inversions observed	Frequency of occurrence (%)
001-199	50	3.1	140	8.6	196	12.1
200-399	133	8.2	252	15.5	81	5.0
400-599	91	5.6	177	10.9	6	0.4
600-799	74	4.5	118	7.3	0	-
800-999	54	3.3	58	3.6	0	-
≥ 1000	105	6.5	48	3.0	0	-

May through October:

1622 soundings approximately 9 years of record).
1158 inversions observed (frequency = 71.4%) of which 456 were with base at the surface, and 702 were with base above the surface.

001-199	162	10.0	225	13.9	62	3.8
200-399	257	15.8	159	9.8	6	.4
400-599	128	7.9	48	3.0	0	-
600-799	53	3.2	11	0.7	0	-
800-999	27	1.7	2	.1	0	-
≥ 1000	18	1.1	0	-	0	-

Fairbanks, Alaska *

November through April:

3188 soundings (approximately 9 years of record).
2862 inversions observed (frequency = 89.8%) of which 2186 were with base at the surface, and 676 were with base above the surface.

	Temperature gradient (°C/100 m)					
	0.1 to < 1.0°		1.0 to < 3.0°		≥ 3.0°	
Thickness (m)	Number of inversions observed	Frequency of occurrence (%)	Number of inversions observed	Frequency of occurrence (%)	Number of inversions observed	Frequency of occurrence (%)
001-199	164	5.1	274	8.6	335	10.5
200-399	219	6.9	267	8.4	227	7.1
400-599	133	4.2	222	7.0	82	2.6
600-799	99	3.1	191	6.0	8	0.2
800-999	83	2.6	131	4.1	0	-
≥ 1000	174	5.5	253	7.9	0	-

* Computations based on 1200 and 2400 Z observations.

Table IV (Cont'd). Frequency of inversion occurrence, in terms of thickness and temperature gradient, for two 6-month periods.

Fairbanks, Alaska*(Cont'd)

May through October:

3187 soundings (approximately 9 years of record).
1510 inversions observed (frequency = 47.4%) of which 1171 were with base at the surface, and 339 were with base above the surface.

	Temperature gradient (°C/100 m)					
	0.1 to < 1.0°		1.0 to < 3.0°		≥ 3.0°	
Thickness (m)	Number of inversions observed	Frequency of occurrence (%)	Number of inversions observed	Frequency of occurrence (%)	Number of inversions observed	Frequency of occurrence (%)
001-199	180	5.6	248	7.8	125	3.9
200-399	295	9.2	282	8.8	19	0.6
400-599	158	5.0	88	2.8	0	-
600-799	56	1.8	24	0.8	0	-
800-999	17	0.5	5	0.2	0	-
≥ 1000	13	0.4	0	-	0	-

Mould Bay, Canada

November through April:

1727 soundings (approximately 10 years of record).
1673 inversions observed (frequency = 96.9%) of which 1239 were with base at the surface, and 434 were with base above the surface.

	Temperature gradient (°C/100 m)					
	0.1 to < 1.0°		1.0 to < 3.0°		≥ 3.0°	
Thickness (m)	Number of inversions observed	Frequency of occurrence (%)	Number of inversions observed	Frequency of occurrence (%)	Number of inversions observed	Frequency of occurrence (%)
001-199	35	2.0	76	4.4	56	3.2
200-399	63	3.6	185	10.7	46	2.7
400-599	56	3.2	220	12.8	19	1.1
600-799	60	3.5	207	12.0	4	0.2
800-999	72	4.2	179	10.4	0	-
≥ 1000	222	12.9	173	10.0	0	-

May through October:

1804 soundings (approximately 10 years of record).
1543 inversions observed (frequency = 85.5%) of which 376 were with base at the surface, and 1167 were with base above the surface.

Thickness (m)	Number of inversions observed	Frequency of occurrence (%)	Number of inversions observed	Frequency of occurrence (%)	Number of inversions observed	Frequency of occurrence (%)
001-199	148	8.2	264	14.6	79	4.4
200-399	264	14.6	235	13.0	19	1.1
400-599	177	9.8	112	6.2	0	-
600-799	102	5.7	43	2.4	0	-
800-999	56	3.1	11	0.6	0	-
≥ 1000	29	1.6	4	0.2	0	-

Nome, Alaska*

November through April:

3354 soundings (approximately 9 years of record).
2384 inversions observed (frequency = 71.1%) of which 1716 were with base at the surface, and 668 were with base above surface.

	Temperature gradient (°C/100 m)					
	0.1 to < 1.0°		1.0 to < 3.0°		≥ 3.0°	
Thickness (m)	Number of inversions observed	Frequency of occurrence (%)	Number of inversions observed	Frequency of occurrence (%)	Number of inversions observed	Frequency of occurrence (%)
001-199	223	6.6	409	12.2	419	12.5
200-399	272	8.1	202	6.0	63	1.9
400-599	169	5.0	114	3.4	14	0.4
600-799	114	3.4	56	1.7	0	-
800-999	92	2.7	42	1.3	0	-
≥ 1000	146	4.4	49	1.5	0	-

* Computations based on 1200 and 2400 Z observations.

Table IV (Cont'd). Frequency of inversion occurrence, in terms of thickness and temperature gradient, for two 6-month periods.

Nome, Alaska* (Cont'd)

May through October:

3552 soundings (approximately 9 years of record).
1755 inversions observed (frequency = 49.4%) of which 986 were with base at the surface, and 769 were with base above the surface.

	Temperature gradient (°C/100 m)					
	0.1 to < 1.0°		1.0 to < 3.0°		≥ 3.0°	
Thickness (m)	Number of inversions observed	Frequency of occurrence (%)	Number of inversions observed	Frequency of occurrence (%)	Number of inversions observed	Frequency of occurrence (%)
001-199	231	6.5	341	9.6	217	6.1
200-399	361	10.2	197	5.5	13	0.4
400-599	167	4.7	50	1.4	0	-
600-799	87	2.4	13	0.4	0	-
800-999	52	1.5	0	-	0	-
≥ 1000	26	0.7	0	-	0	-

* Computations based on 1200 and 2400 Z observations.

Thule, Greenland

November through April:

920 soundings (approximately 5 years of record).
805 inversions observed (frequency = 87.5%) of which 684 were with base at the surface, and 121 were with base above the surface.

	Temperature gradient (°C/100 m)					
	0.1 to < 1.0°		1.0 to < 3.0°		≥ 3.0°	
Thickness (m)	Number of inversions observed	Frequency of occurrence (%)	Number of inversions observed	Frequency of occurrence (%)	Number of inversions observed	Frequency of occurrence (%)
001-199	75	8.2	153	16.6	171	18.6
200-399	76	8.3	102	11.1	18	2.0
400-599	28	3.0	69	7.5	1	.1
600-799	25	2.7	39	4.3	0	-
800-999	6	.6	19	2.1	0	-
≥ 1000	17	1.8	6	.6	0	-

May through October:

977 soundings (approximately 5 years of record).
587 inversions observed (frequency = 60.1%) of which 244 were with base at the surface, and 343 were with base above the surface.

001-199	103	10.5	126	12.9	48	4.9
200-399	133	13.6	59	6.0	5	.5
400-599	63	6.5	22	2.3	0	-
600-799	19	2.0	3	.3	0	-
800-999	2	.2	1	.1	0	-
≥ 1000	3	.3	0	-	0	-

Yakutat, Alaska

November through April:

1621 soundings (approximately 9 years of record).
699 inversions observed (frequency = 43.1%) of which 603 were with base at the surface, and 96 were with base above the surface.

	Temperature gradient (°C/100 m)					
	0.1 to < 1.0°		1.0 to < 3.0°		≥ 3.0°	
Thickness (m)	Number of inversions observed	Frequency of occurrence (%)	Number of inversions observed	Frequency of occurrence (%)	Number of inversions observed	Frequency of occurrence (%)
001-199	162	10.0	177	10.9	99	6.1
200-399	132	8.1	63	3.9	11	0.7
400-599	18	1.1	12	0.7	0	-
600-799	9	0.6	5	0.3	0	-
800-999	5	0.3	1	0.1	0	-
≥ 1000	4	0.2	1	0.1	0	-

Table IV (Cont'd). Frequency of inversion occurrence, in terms of thickness and temperature gradient, for two 6-month periods.

Yakutat, Alaska (Cont'd)

May through October:

1640 soundings (approximately 9 years of record).
451 inversions observed (frequency = 27.5%) of which 108 were with base at the surface, and 343 were with base above the surface.

	Temperature gradient, (°C/100 m)					
	0.1 to < 1.0°		1.0 to < 3.0°		≥ 3.0°	
Thickness (m)	Number of inversions observed	Frequency of occurrence (%)	Number of inversions observed	Frequency of occurrence (%)	Number of inversions observed	Frequency of occurrence (%)
001-199	67	4.1	84	5.1	12	0.7
200-399	121	7.4	47	2.9	1	0.1
400-599	52	3.2	9	0.5	1	0.1
600-799	37	2.2	3	0.2	0	-
800-999	10	0.6	0	-	0	-
≥ 1000	7	0.4	0	-	0	-

APPENDIX A. TYPICAL ARCTIC TEMPERATURE INVERSIONS

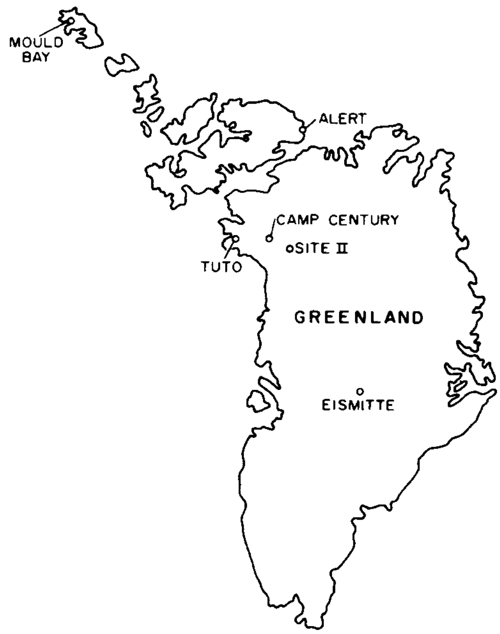

Figure A1. Location map.

Information on temperature inversions on ice sheets is limited because few radiosonde observations have been made in these areas. A thorough search for immediately available material provided short records for three stations on the Greenland ice sheet (Eismitte, Site 2, and Camp Century) and for three other widely separated Arctic stations (Camp Tuto # 1, Alert, and Mould Bay). The locations of these six stations are shown in Figure A1.

The most useful information was obtained from Georgi (1957). This information is unique because it provided temperature soundings on an ice sheet during the winter period. Figure A2 is a reproduction of the temperature profiles taken during the Deutschen Grönland Expedition A. Wegener 1930-31 and Expéditions Polaires Francaises 1949-50 to interior Greenland. The German text* which accompanied the figure was translated by Dr. Fritz Kasten, Environmental Research Branch, as follows:

"The main reason for the soundings was to investigate the temperature inversion; this inversion is formed at a few hundred meters above the ice cap, when in calm "radiation weather" ('Ausstrahlungswetter') the firn surface cools down well below the temperature of the air above the ice cap. Due to the lasting contact, the air layer immediately above the firn cools down as much as the firn itself; the air layers above also cool down due to contact with the colder layers underneath. But one realizes at once that this cooling decreases with increasing height due to the low heat conductivity of the air, until, by sudden transition, the original air temperature is reached again.

"That there is not necessarily a temperature inversion above the surface of the ice cap - although inversions are very frequent - is demonstrated by the two dashed soundings. High wind velocity, particularly, causes strong vertical mixing of the lowest layers even in winter whereby a potential inversion is destroyed. In summer, the firn surface and the incumbent air layer can be warmed up by strong solar irradiation so that the temperature decreases steadily with height; this is represented in the two soundings of 19 January 1950 and 2 September 1930."

Upper air observations during two summer periods were conducted at Site 2, and a brief record (32 days) during the summer-winter transition period was available for Camp Century, Greenland.† The average temperature profiles and the maximum inversions observed are shown in Figures A3 and A4.

*Georgi, J. (1957) Im eis vergraben, Leipzig: Brockhaus Verlag (text in German).

†Department of Commerce (U.S. Weather Bureau). Summary of Constant Pressure Data, Form WBAN - 33. Site II, (Camp Fist Clench), Greenland, May-August 1959, May-August 1960. Camp Century, Greenland, September-October 1960.

The significant points derived from these diagrams are: 1) inversions on the Greenland ice sheet become steeper toward winter and, 2) they appear to be confined to within 400 to 500 m above the snow surface. The average increase in temperature over that height varies from negligible amounts in summer to about 7°C in early winter. Numerical coded soundings from the French expedition at Station Centrale in Greenland indicate the average winter inversion is about 300 m deep with an increase in temperature of 8°C.* Isothermal conditions and instances of decreasing temperatures, however, are common during the summer and can occur at any time of the year.

Soundings were available for Camp Tuto at the edge of the Greenland ice sheet† and two locations at sea level in the Canadian Arctic Archipelago, Alert and Mould Bay.** A plot of the record (only summer months available) for Camp Tuto #1 (Fig. A5) indicates that few inversions can be expected here during this time of the year. The soundings at Alert and Mould Bay could be definitely classified into two seasons: the "light" or summer period and the "dark" or winter period. The temperature profiles from May to near the end of October were isothermal for most of the time or the temperature decreased with height, whereas between November and April the bulk of the soundings showed inversions. The average temperature profiles for these two periods and the maximum inversions observed are shown in Figures A6 and A7.

It is noted that the inversions apparently extend higher (1200 to 1500 m) at stations of lower elevation than on the ice sheet. Also, the average increase in temperature for the winter inversions at the sea level stations approximates 7°C.

Acknowledgements: This research note was prepared with assistance from Dr. Fritz Kasten and Mr. Roy Bates.

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*Victor, P.E. (1950) Recueil des Observations Météorologiques, effectuées par la Station Francaise du Groenland entre le 20 Juillet 1949 et le 14 Juillet 1950, Expéditions Polaires Francaises.

†Department of Commerce (U.S. Weather Bureau). Summary of Constant Pressure Data, Form WBAN - 33. Camp Tuto (Station I), Greenland, May-September 1958.

**Department of Transport (Canada), Arctic Summary, Semi-annual Summary of Meteorological Data from Weather Stations on the Canadian Arctic Islands. Department of Transport, Meteorological Branch, January 1960-June 1961.

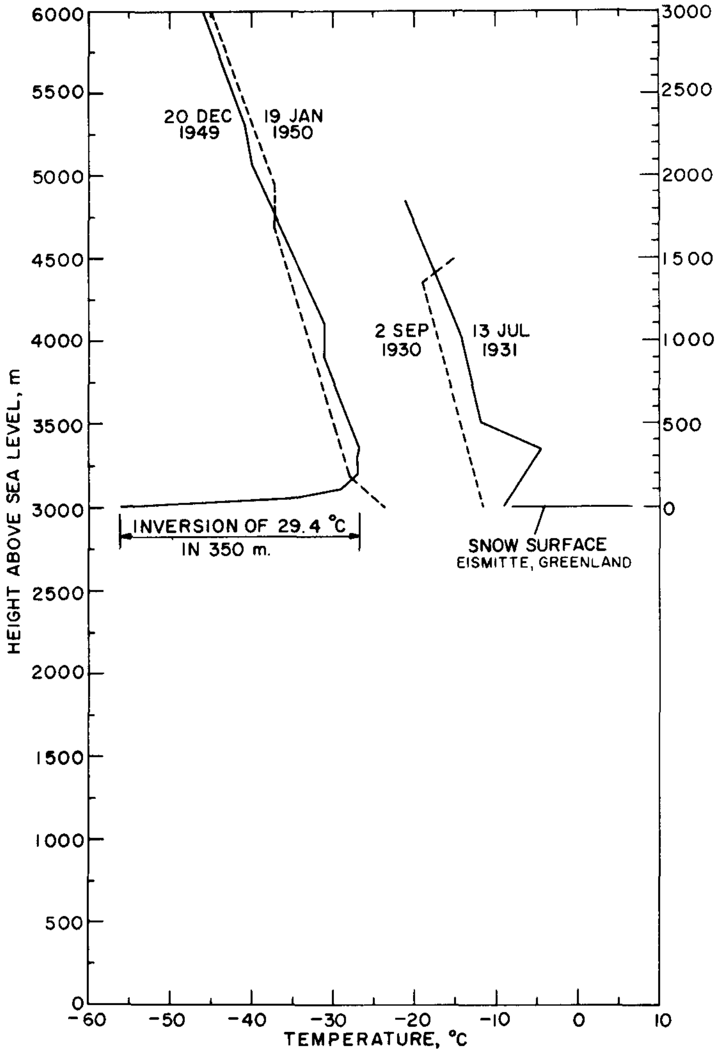

Figure A2. Temperature profiles, Eismitte, Greenland 1930-31 and 1949-50.

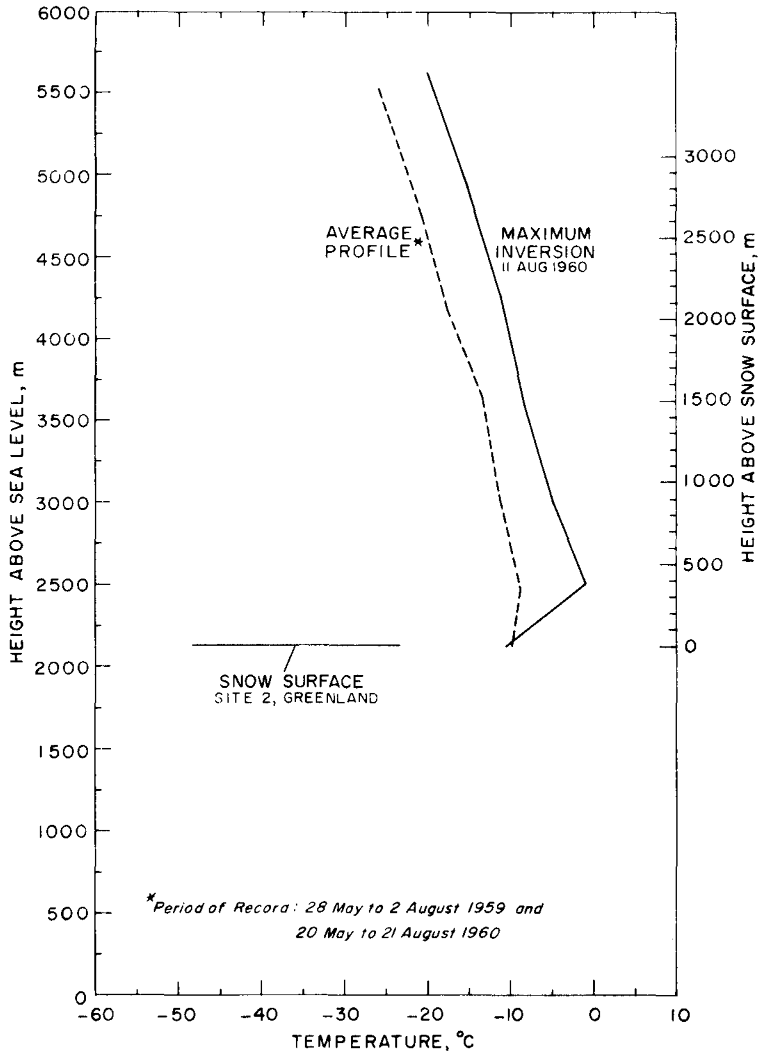

Figure A3. Temperature profiles, Site 2, Greenland.

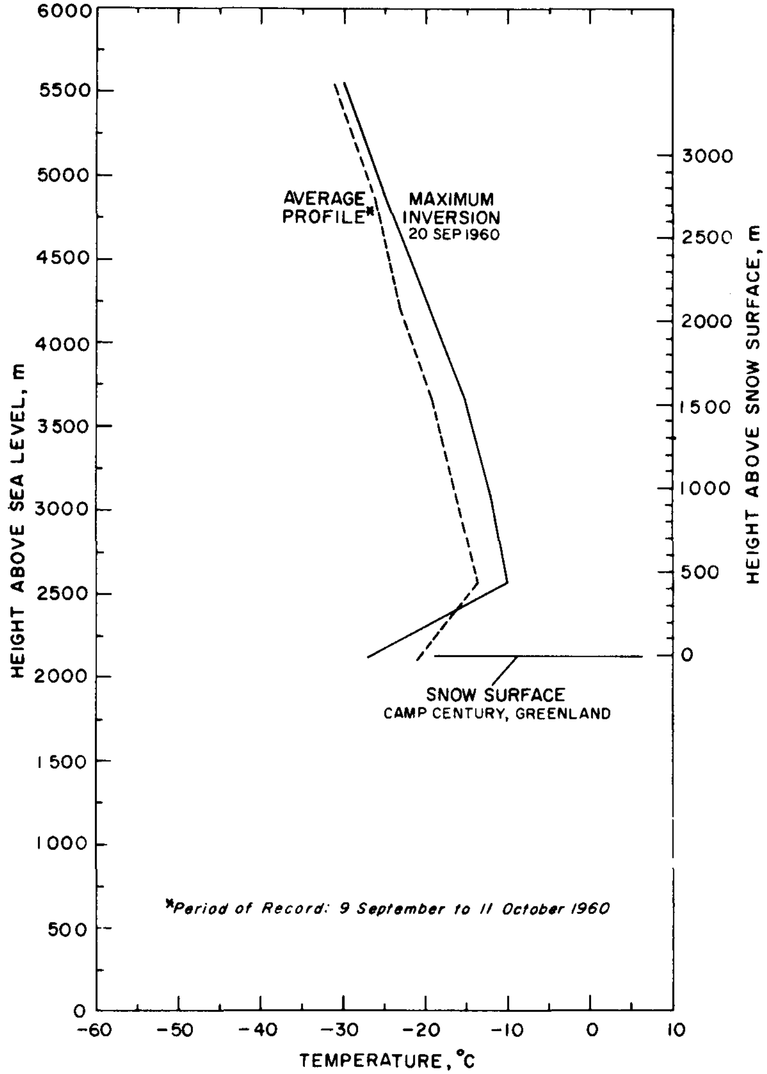

Figure A4. Temperature profiles, Camp Century, Greenland.

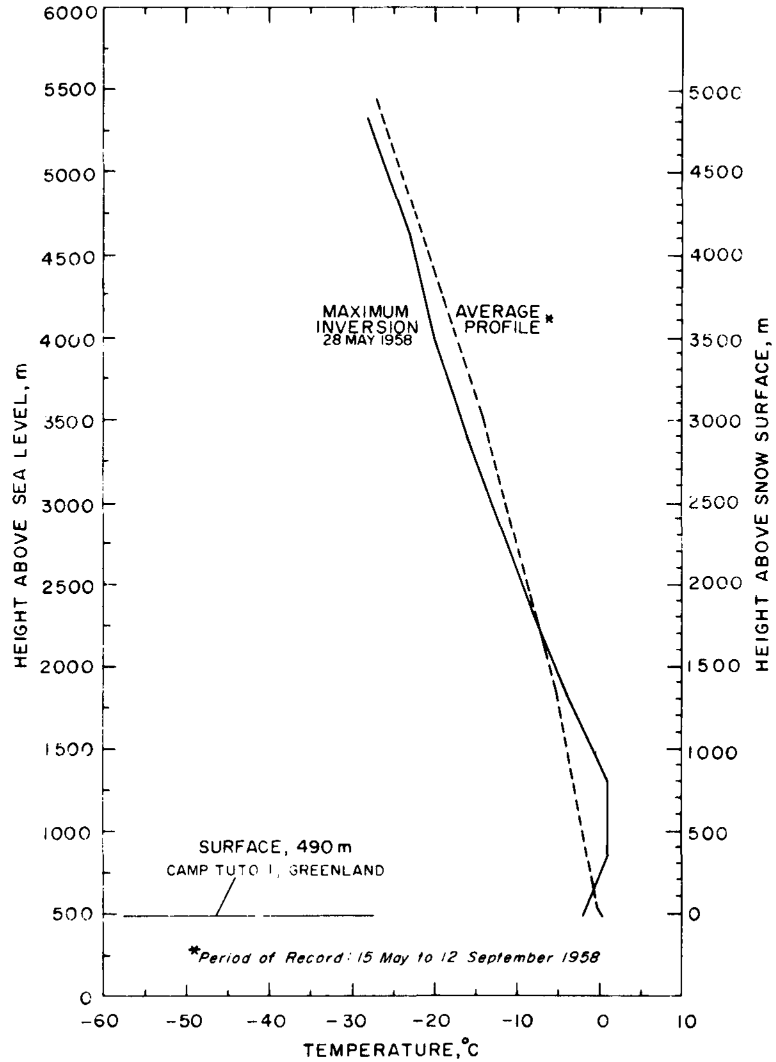

Figure A5. Temperature profiles, Camp Tuto # 1.

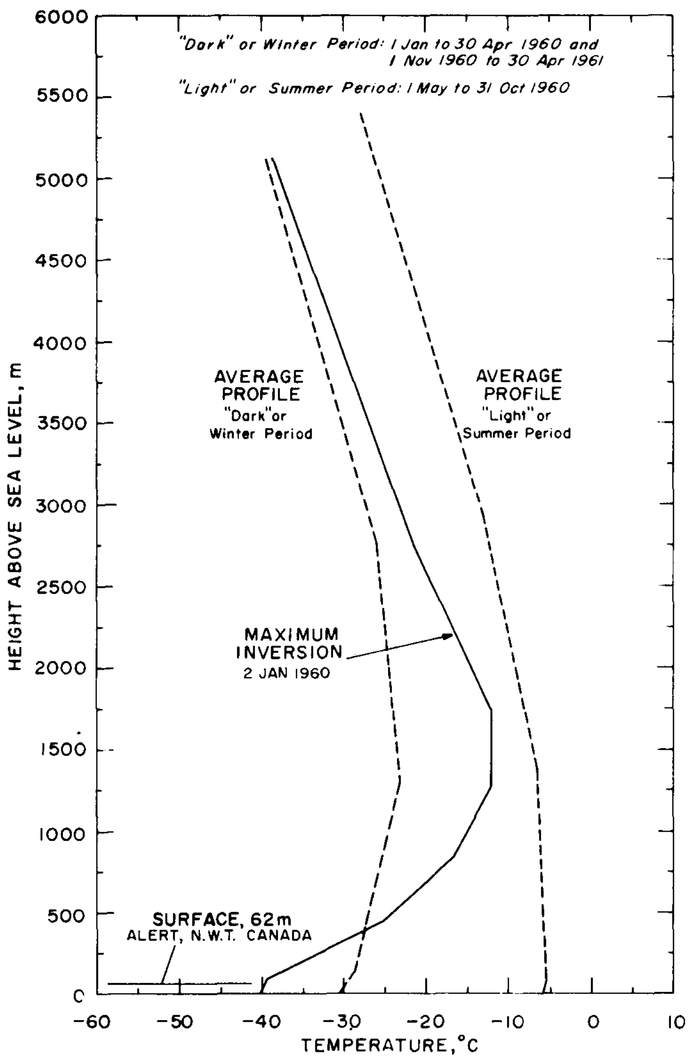

Figure A6. Temperature profiles, Alert, N. W. T., Canada.

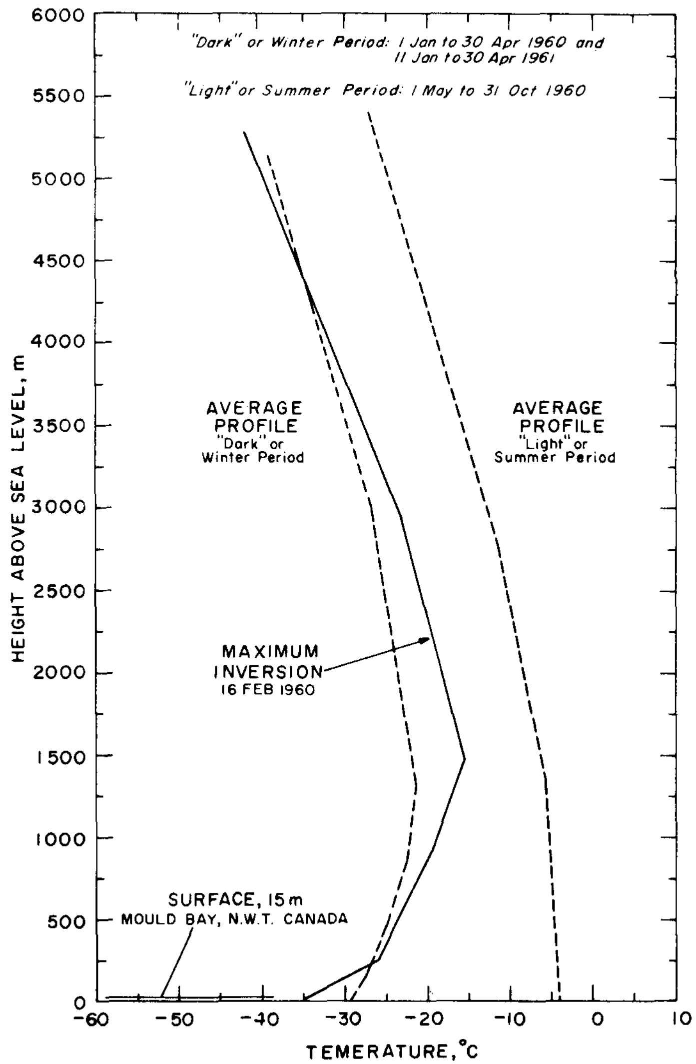

Figure A7. Temperature profiles, Mould Bay, N. W. T., Canada.

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4. DESCRIPTIVE NOTES (*Type of report and inclusive dates*)
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13. ABSTRACT

This study provides a statistical analysis of available data on Arctic and subarctic inversions, and includes data from locations in Canada, Greenland, and Alaska. The analysis considers inversions with respect to frequency, base height, thickness, base temperature, and temperature gradient.

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14. KEY WORDS	LINK A		LINK B		LINK C	
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