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EXTRACTION AND COMPILATION OF AVAILABLE TEMPERATURE & SNOW-FALL DATA IN THE UNGAVA PENINSULA AS INPUT TO GEOTHERMAL MODELLING OF QUATERNARY PALAEOCLIMATES

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Earth Physics Branch Open File Number 83-12
Ottawa, Canada, 1983

Price/Prix: $8.00

Abstract

This report presents information on recent air and ground temperature, snowfall, snow cover amounts and duration from as many locations as possible for the Ungava Penninsula. It is presented in the form of tables, diagrams and maps with an accompanying interpretative text.

Résumé

Ce rapport presenté un recueil d'information sur les température récente de l'air et du sol, épaisseur et la duré du couvert nival pour le plus grand nombre possible de stations dans le peninsule d'Ungava. L'information est presenté sans forme de tableaux, diagrammes et cartes et accompagné d'une discussion interprétative.

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March 31st, 1983.

Report submitted to the Earth Physics Branch, Energy, Mines and Resources, Canada, in fulfillment of a research contract (file no.: MAS 20SU . 23235-2-1385, serial no.: OSU82-00401).

ABSTRACT

In connection with ongoing efforts of the Geothermal Studies Division of the Earth Physics Branch to study active layer and permafrost evolution and to model paleoclimatic change using deep hole temperature cables in the Ungava Peninsula, the parameters of recent air and ground temperatures, and of snow-fall and snow cover amounts and duration, are of extremely great importance. In the framework of the present contract, such information has been extracted for as many locations as possible, from available records. It is presented in this report in the form of tables, diagrams and maps with an accompanying interpretative text. The following parameters were analysed:- mean annual air temperatures and their regional fluctuations from 1930 to 1980; mean annual ground temperatures (surface to 150 cm) for the Kujjuaq (Fort Chimo) meteorological station; atmospheric thawing and freezing indices in °C/days; mean annual snow-fall in terms of spatial and temporal fluctuations; average snow-pack thickness and duration; and a snow cover index in cms/days.
The discussion of the data emphasises possible spatial contrasts for the Ungava region in relation to latitude, continentality and altitude as well as temporal fluctuations measured for the past fifty years and tentatively extrapolated for the last hundred years.

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CHAPTER 1: INTRODUCTION

Definition of parameters

The thermal regime beneath the ground surface is, in part, a function of sub-surface thermal properties (heat storage capacity, latent heat exchange potential and thermal conductivity), in part a function of the heat flux through the crust from the earth's interior, but, most importantly, a function of the seasonal heating and cooling of the earth's atmosphere. Winter cooling results in a net flow of heat energy out of the ground; summer heating results in a net flow of heat energy into the ground.

In the southern part of the Quebec-Labrador Peninsula, where permafrost occurs only sporadically, these reversing heat flows lead to seasonal freezing and thawing of a sub-surface layer from a few centimetres to a few metres thick. As one progresses northward in the Peninsula, the thermal regime in the ground becomes cooler, and permafrost becomes more widespread, and then continuous near the treeline in the Ungava region. The seasonal reversals of heat flow find their expression in the development, each summer, of a thaw layer on top of the permafrost table - known as the active layer. The latter varies from a few decimetres up to $\sim$5 m in thickness, depending on various microclimatic and terrain factors.

There are several ways to express the heat flux between the atmosphere and the ground surface at any given site. In energy balance terms it can be expressed as a net quantity of energy, in joules/m^{-2}, flowing into or out of the ground, for any specified time interval. However, the energy balance is subject to extremely great local fluctuations in accordance with terrain and surface cover variations. This local variability tends to mask contrasts on a regional scale. A further disadvantage is that the basic data for calculating energy exchange is not available for the climatic stations in Ungava. Air temperatures are a better, and more readily available, index of regional contrasts in heating and cooling of the ground surface. Mean annual air temperatures are therefore used to assess the net effect of heating and cooling. Where data is available for several decades, it is possible to ascertain long term trends towards sub-surface heating or cooling. The ranges between mean July and January air temperatures give some idea of the effects of continentality on the thermal regime.

For the Ungava region, the available energy for active layer development can be assessed in terms of the thawing index, calculated as the average annual total of °C/days above 0°C. The freezing index, expressed in °C/days below 0°C, is of more intrinsic interest in the southern part of Quebec-Labrador, in relation to the development of the seasonally frozen layer, but it is also shown for stations in Ungava.

Mean annual ground surface temperature is clearly a parameter of more direct importance than air temperature, for the sub-surface thermal regime, but, as in the case of the energy balance, it is subject to extreme local fluctuations, due to variability in surface characteristics, notably:- vegetation cover, snow cover and aspect. Furthermore, data on this parameter has only been systematically collected for single sites at Kuujjuaq and Schefferville meteorological stations. The Kuujjuaq data has been reproduced in summary form in this report, along with a few values deduced from ground temperature cables at various localities in the Peninsula.

Snow cover is undoubtedly one of the surface factors principally responsible for variations in atmosphere - ground heat flux, on both a regional and a local scale. That snow cover shows considerable local variations in Québec-Labrador is well known from a number of studies by Adams and Findlay (1966), Thom and Granberg (1970), Nicholson and Granberg (1973), Filion and Payette (1976, 1978), Gray et al (1979), Poitevin and Gray (1982), amongst others. These local variations must, of course, be considered as of primary importance in any study of ground temperature regimes. Less well known, but probably of considerable secondary significance, are the regional contrasts in snow cover across the Peninsula. In this report, these contrasts are presented in terms of mean annual snow-fall totals, average snow pack thickness and duration. and a snow cover index measured in cm/days. The great variability of snow cover from year to year can be superimposed on these local and regional variations, in order to determine whether significant long term trends exist or not.

Location of data sites

Figure 1 shows the location of principal and secondary data sites used in this study within and on the fringes of Ungava. Table 1 gives detailed information on the length of operation of the stations and on the nature and quality of the data used in this study. It is immediately obvious that the biggest problem in climatic interpretation stems from the almost total absence of good long term data from the interior of Ungava. The effects of increased continentality and altitude within the Ungava Peninsula are not truly ascertained by the available data, although they can to some extent be surmised.

Data sources

The climatic data used in this report was extracted from micro-film data kept in the records of the Atmospheric Environment Service of the Government of Canada, from several volumes of the Canadian Climate Normals 1951-1980, (Environment Canada), and from published ground temperature data from various sources listed in the text and in the tables in this report.

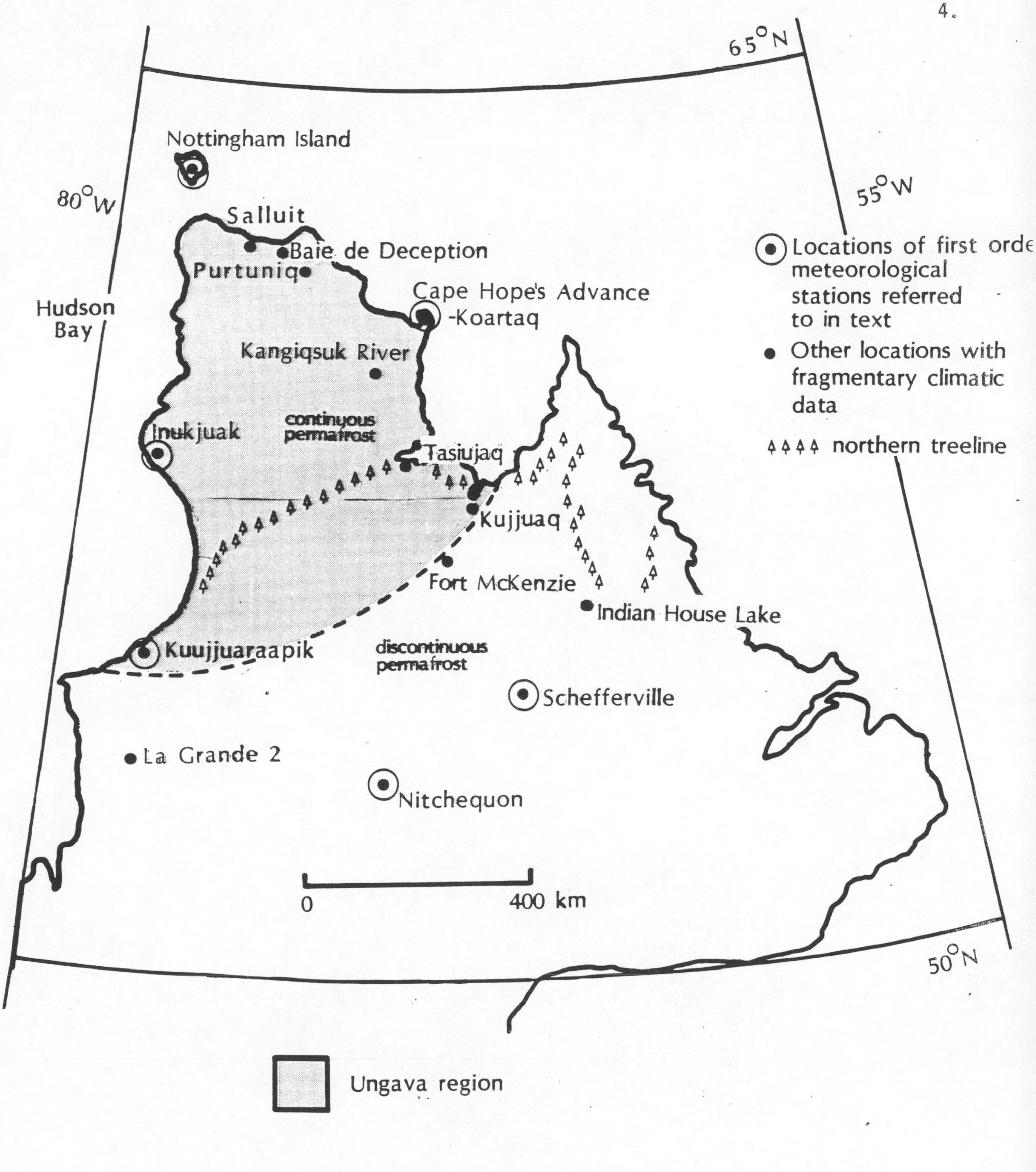


Figure 1: Ungava region and locations of climatic data used in the study.

TABLE 1 UNGAVA SITES WITH RECENT TEMPERATURE AND/OR SNOW DATA

Station	Latitude	Longitude	Altitude (m)	Period of relatively continuous record	Information Available	Comments
PRINCIPAL SITES						
Nitchequon	53°12'N	70°54'W	536	1943-1980 (38 years)	Air temperature snowfall, snow course data	Excellent
Schefferville	54°48'N	66°49'W	522	1949-1980 (32 years)	" "	Excellent
Kuujjuaraapik (Poste de la Baleine)	55°17'N	77°46'W	18	1926-1980 (55 years)	" "	Generally good
Kuujjuaq (Fort Chimo)	58°06'N	68°25'W	37	1947-1980 (34 years)	" "	Excellent (includes ground temp. data
Inukjuak (Port Harrison)	58°27'N	78°07'W	5	1938-1980 (43 years)	" "	Excellent
Cape Hope's Advance/ Koartaq	61°05'N	69°33'W	73/27	1929-1980 (52 years)	" "	"
Nottingham Island	63°7'N	77°56'W	16	1930-1970 (41 years)	Air temperatures, snow-fall	"
OTHER SITES						
Indian House Lake	56°14'N	64°44'N	311	1947-1964 (18 years)	" "	"
Fort Mackenzie	56°53'N	69°03'W	76	1938-1951 (13 years)	" "	"
Tasiujaq (Baie-aux-Feuilles)	58°41'N	69°56'W	0-100	1976-1977 (1 year)	Spring survey of snow depth	One year snow survey
Kangiqsuk River (Payne River)	60°06'N	71°04'W	6	1954-1958 (5 years)	Air temperatures, snow-fall	Moderate
Purtuniq (Asbestos Hill)	61°49'N	73°55'W	484	1961-1963 (3 years)	Air temperatures snow-fall	Fragmentary
Baie de Déception	62°07'N	74°37W	30	1964-1973 (10 years)	"	Fragmentary to moderate
Salluit (Saglouc)	62°12'N	75°38'W	15	1966-1967	"	Fragmentary
La Grande	53°38'N	77°42'W	191	1976-1980	"	Good

CHAPTER 2: TEMPERATURE DATA

Air temperatures - mean annual, January and July values

Figure 2 shows regional variations in mean annual air temperatures across the Ungava Peninsula, the data being summarised for each station in Table 2. In general, the mean annual isotherm for -5 to -6° C corresponds with the treeline in southern Ungava and with the transition from discontinuous to continuous permafrost. The temperature gradient follows a generally northerly direction, the coldest temperatures (~ -11°C) occurring at 500-600 m altitude on the interior plateau of northernmost Ungava near Purtuniq. The lack of interior stations does not permit the effect of continentality on air temperatures in Ungava to be easily recognised. The limited amount of data that does exist shows January - July temperature ranges of 35 to 38°K for the stations of Schefferville, Nitchequon, Indian House Lake and Fort Mackenzie, in the heartland of the Quebec-Labrador Peninsula. Corresponding temperature ranges for stations Kuujjuaraapik and Inukjuak on the Hudson Bay coast, Kuujjuaq and Cape Hope's Advance - Koartaq on the Ungava Bay coast and Nottingham Island and Baie de Deception on the Hudson Strait coast vary between 31 and 35°K. The contrast between coastal and interior stations is minimal. The cooling effects of cold seas on the coastal stations in the summer is apparently compensated by the greater altitude of the interior stations. In the winter, maritime influences are reduced with the development of an ice cover on the bordering seas, and the principal influences on air temperature become latitude and altitude. No point on the Ungava Peninsula is further than 200-250 km from the sea and there are no major topographic barriers to the movement of air masses across the Peninsula, this mitigating expected contrasts in annual air temperatures between coastal and interior stations.
As far as altitude is concerned, the interior plateau in Ungava reaches elevations of 300-500 m in the southern part of the Peninsula, but attains elevations of 500-650 m in the northern part of the Peninsula, in the Wakeham Bay - Cape Smith fold belt of the Labrador geocyncline (around Purtuniq for example). These altitudes may be responsible for

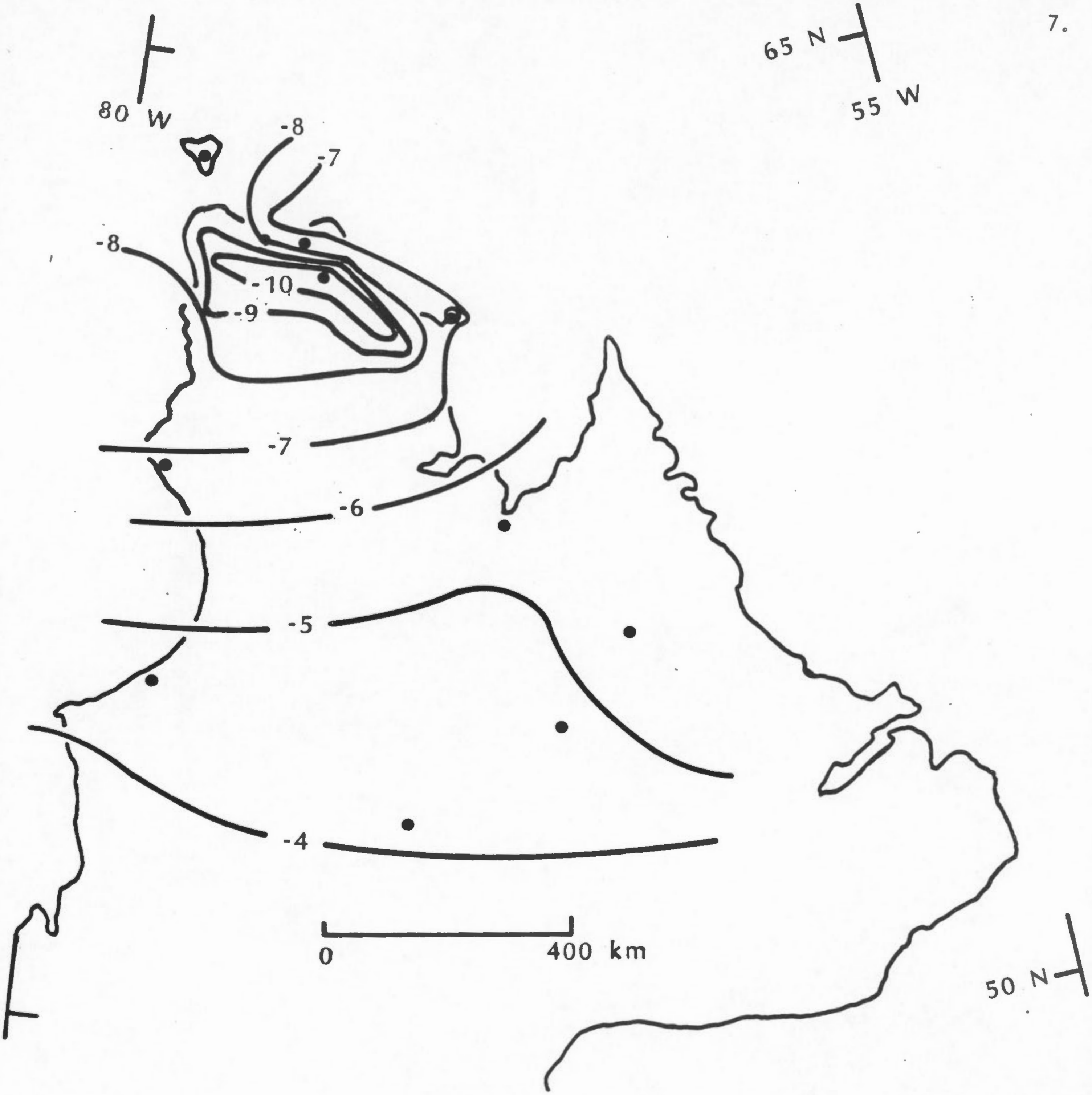


FIGURE 2: ISOTHERMS FOR MEAN ANNUAL AIR TEMPERATURES (0°) IN UNGAVA

TABLE 2: AIR TEMPERATURE DATA, THAWING AND FREEZING INDICES FOR UNGAVA REGION, FOR THE PERIOD 1951-1980.

Site	Air temperatures (°C)			Thawing index	Freezing index
	Mean Annual	July	January	°C/days	°C/days
Nitchequon	-4.1	13.6	-23.0	1,439	2,889
Schefferville	-4.8	12.6	-22.8	1,268	2,980
Kuujjuaraapik	-4.3	10.5	-22.5	1,241	2,815
Indian House Lake	-5.4	12.0	-22.9	1,156	3,093
Fort Mackenzie*	-4.9	12.2	-25.6	-	-
Kuujjuaq	-5.5	11.4	-23.3	1,147	3,128
Inukjuak	-6.7	9.3	-24.5	920	3,330
Kangiqsuk River	-7.7	10.7	-25.9	889	~ 3,590
Cape Hope's Advance/ Koartaq	-7.0	5.8	-21.5	526	3,094
Baie de Déception	-7.2	9.4	-24.4	812	-
Purtuniq	-10.7	8.7	-27.9	-	-
Nottingham Island	-8.7	6.3	-24.4	501	3,636

* Normalised for 1941-1970.

a reduction of mean annual air temperatures in the order of 1.5°C to 3°C. This influence is evident in the isotherms for northern Ungava in figure 2.

Recent fluctuations in air temperatures in Ungava

Figure 3 shows recent trends of mean annual air temperatures at six stations around the margins of the Ungava Peninsula. These trends reveal a general increase in temperatures from 1930 till 1960 and then a decrease from 1960 until 1980. Table 3 shows fluctuations of mean annual temperatures plotted by decade backwards from the 1970-1980 decade. This data is plotted graphically on Figure 4 and shows a general increase of 1.5°K from 1925 to 1955 succeeded by a decrease of 1°K from 1955 to 1975. Extrapolation further back in time is hazardous as no data is available from northern stations, but tentative estimates of air temperatures for the decade between 1920 - 1930 and 1870 - 1880 have been made in Table 4, on the basis of comparisons of century long records from the Anticosti Island - Sept Isles stations, and from the Pointe-au-Pic - Rimouski stations, in the lower St. Lawrence region of southern Quebec. The fluctuations between 1925 and 1875 appear to have been relatively slight (0.0 - 0.3°K) with the exception of a temporary plunge in the order of 0.6°K for the decade 1880 - 1890.

Ground surface temperatures

Long term ground surface temperature data is extremely scarce for Ungava. Soil temperature records have been kept since 1967 for depths of 5cm, 10cm, 20cm, 50cm, 100cm and 150 cm at a thermistor installation at the Kuujjuaq weather station. Figure 5 summarises the distribution of mean annual temperatures at all depths and at screen level for the time period of 1967 - 1978. The mean ground surface temperatures are approximately 4°K warmer than the air temperatures at the site. Table 5 shows that this differential is not constant throughout the year but varies between a high of 6.1°K in December and a low of 1.6°K in September. The insulative effect of the snow cover of the winter months between mid November and late May

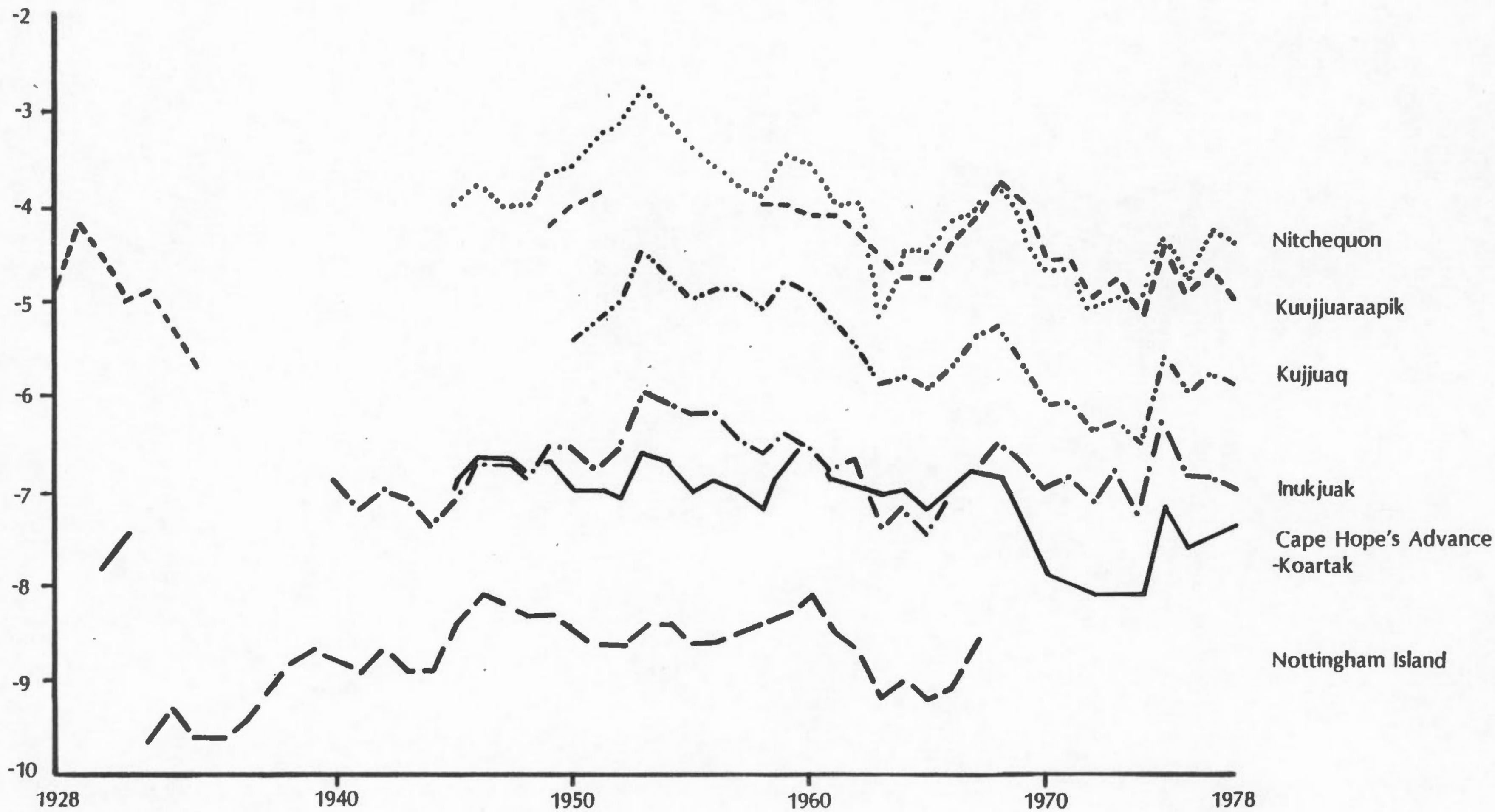


FIGURE 3: RECENT TRENDS OF MEAN ANNUAL AIR TEMPERATURES FOR THE UNGAVA REGION, BASED ON 5 YEAR RUNNING MEANS/

TABLE 3: CUMULATIVE MEAN ANNUAL AIR TEMPERATURE CHANGES AT METEOROLOGICAL STATIONS IN UNGAVA, BY DECADES FROM 1980 to 1920.

STATION	CUMULATIVE TEMPERATURE CHANGE (°K)					
	1980-70	1970-60	1960-50	1950-40	1940-30	1930-20
Schefferville	0	+0.3	+1.0	-	-	-
Nitchequon	0	+0.5	+1.4	+0.5	-	-
Kuujjuaraapik (Poste de la Baleine)	0	+0.5	+1.3	+0.4	-0.1	0.0
Inukjuak	0	-0.1	+0.6	-0.1	-0.6	-0.9
Cape Hope's Advance -Koartaq	0	+0.8	+1.0	+0.6	+0.2	-0.1
Kuujjuaq(Fort Chimo)	0	+0.4	+1.2	+0.3	-	-
Mean change	0	+0.4	+1.1	+0.3	-0.2	-0.3

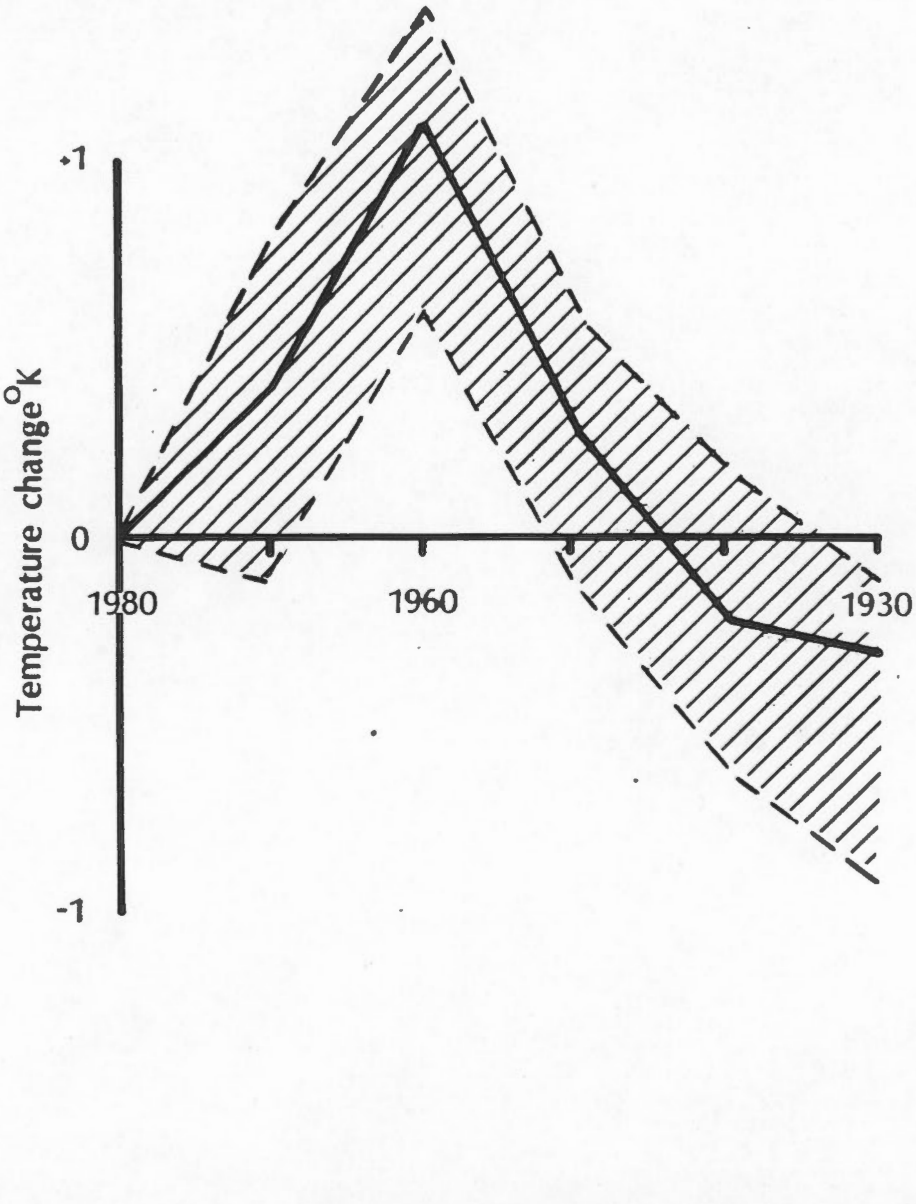


FIGURE 4: MEAN ANNUAL TEMPERATURE FLUCTUATIONS IN °K BY DECADE FROM 1980 to 1930. The mean values and the range of values for these fluctuations are shown by the solid line and the d ed lines respectively for the six meteorological stations in Table 3.

TABLE 4: MEAN ANNUAL TEMPERATURE FLUCTUATIONS IN UNGAVA EXTRAPOLATED FROM 1980 BACKWARDS TO 1870.

Decade	Amplitude of cumulative temperature from 1980-1970 backwards in time (°K)	
	Ungava Stations	Southern Quebec Stations
1980 - 1970	0.0	0.0
1970 - 1960	+0.4	+0.4
1960 - 1950	+1.1	+0.7
1950 - 1940	+0.3	+0.5
1940 - 1930	-0.2	+0.2
1930 - 1920	-0.3	-0.6
1920 - 1910	-0.3*	-0.6
1910 - 1900	0.0*	-0.3
1900 - 1890	0.0*	-0.3
1890 - 1800	-0.6*	-0.9
1980 - 1870	-0.2*	-0.5

* Values extrapolated by comparison with fluctuations observed for Southern Quebec Stations (Anticosti SW and Pointe-au-Pic/Rimouski)

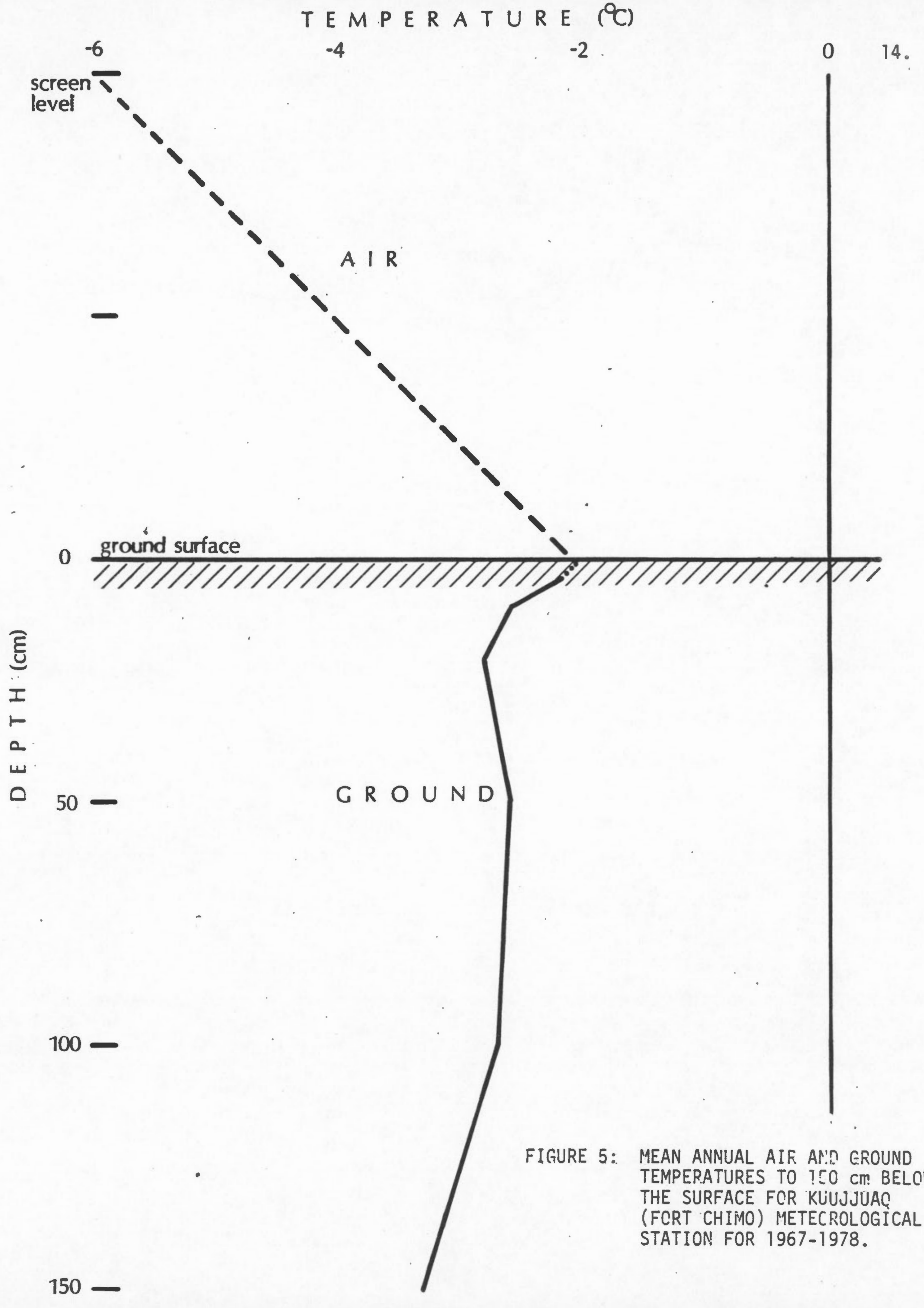


FIGURE 5: MEAN ANNUAL AIR AND GROUND TEMPERATURES TO 150 cm BELOW THE SURFACE FOR KUUJJUAQ (FORT CHIMO) METEOROLOGICAL STATION FOR 1967-1978.

TABLE 5: MEAN MONTHLY DIFFERENTIALS BETWEEN AIR AND GROUND TEMPERATURES FOR 1967 - 1978 AT KUUJJUAQ (FORT CHIMO)

Month	Air temperature (°C)	Ground temperature at 5 cm depth (°C)	Differential (°K)	Snow Cover at Station (cms)
January	-24.0	-18.4	+5.6	45
February	-22.7	-19.2	+3.5	52
March	-19.2	-16.0	+3.2	56
April	10.8	-5.9	+4.9	47
May	-0.2	4.1	+4.3	23
June	6.6	10.6	+4.0	3
July	11.2	14.9	+3.7	-
August	9.8	12.8	+3.0	-
September	5.0	7.0	+2.0	-
October	-0.9	0.7	+1.6	5
November	-8.1	-4.3	+3.8	15
December	-18.8	-12.7	+6.1	32
Mean annual	-6.0	-2.2	+3.8	

give the greatest contrasts between air and ground surface temperatures (3°K - 6°K). Possibly variations throughout the winter and spring months are caused by such factors as varying snow depth, increasing densification of the snow pack and latent heat exchange during the spring melt. The contrast for the snow-free months of June, July and August remains at a level of 3°K - 4°K, possibly due to the relatively high albedo of the surface which is non vegetated land-fill. In the fall months of September and October the contrast is only 1.6°K - 2°K; albedo effects are not so important, as radiation receipts decline drastically at this time of the year, and a snow cover does not yet blanket the ground.

Table 6 lists ground surface temperatures in relation to air temperatures for a) a number of drill-hole sites with temperature cables and b) for Kuujjuaq and Schefferville meteorological stations. Exposed sites characterised by a low snow cover show differentials of 3.5 up to 5.5°K; lichen woodland sites with moderate snow cover, and snow-drifted depressions in the tundra zone show differentials of 6.3 to 8.3°K.

Thawing and freezing indices

Figures 6 and 7 show the annual thawing and freezing indices, respectively in °C/days above and below 0°C at screen level for Ungava. The data is also listed in Table 2. The value of these indices are that they are an index of the total amount of energy available for seasonal thawing or freezing of the near surface layer. The data can be applied to frost or thaw penetration models either with or without corrections for surface factors. Lunardini (1978) for example attempts to apply factors of correction to the air thawing index in order to obtain a ground surface thawing index. Gray et al (1979) were able to relate depth of thaw directly to an air thawing index; in the latter case different terrain types resulted in varying regression line gradients. Isolines for both the thawing and freezing indices show that latitudinal influences prevail - gradients are generally north to south, with a slight depression of the freezing index isolines towards the south over the continental zones reflecting the influence of topography and continentality. Although not shown in Figure 6, it is possible that the northern Ungava plateau near Purtuniq may be characterised by a thawing index of less than 500°C/days due to the high altitude (~ 500 m).

TABLE 6: GROUND SURFACE TEMPERATURES IN RELATION TO AIR TEMPERATURES FOR EXPOSED AND SNOW-DRIFT SITES IN UNGAVA

Location	Site Characteristics	Estimated mean annual ground surface temperature (°C)	Estimated mean annual air temperature (°C)	Differential between surface & air temperature (°K)	Reference
La Grande 2	a) Disturbed terrain - low snow cover.	1.5 to 1.8	-3.7	5.2 to 5.5	Poitevin (1983)
	b) Natural terrain; peat bog, woodland, burn (snow cover 0.5-1m)	2.6 to 4.6	"	6.3 to 8.3	
Kuujjuaraapik	a) GB1 -2 drill holes on very exposed bedrock summit	-2.0 to 3.0	-5.3[1]	2.3 to 3.3	Poitevin & Gray (1982)
	b) Domanchin - drill holes in depression with 1m snow cover	+1.0	"	6.3	
Schefferville	Weather station, 1cm depth, snow cover ~0.5 m, moderately exposed	-1.4	-5.1[2]	3.7	Environment Canada records
Kuujjuaq (Fort Chimo)	Weather station 5cm depth snow cover ~0.5 m, moderately exposed.	-2.2"	-6.0[3]	3.8	Phillips & Aston 1979 Environment Canada
Tasiujaq (Lac Jourdan)	a) C97- snow hollow	0.0	-6.5	6.5	Gray et al 1979
	b) C109- relatively exposed	-3.0	"	3.5	
	c) C111- " "	-3.0	"	3.5	
Purtuniq	Asbestos Corporation drill-holes (snow depths unknown)	-6.6	-10.7	4.1	Taylor & Judge (1979

1. Corrected for altitude
2. For two year period Oct. 1964 - Sept. 1966
3. For period 1967 - 1978.

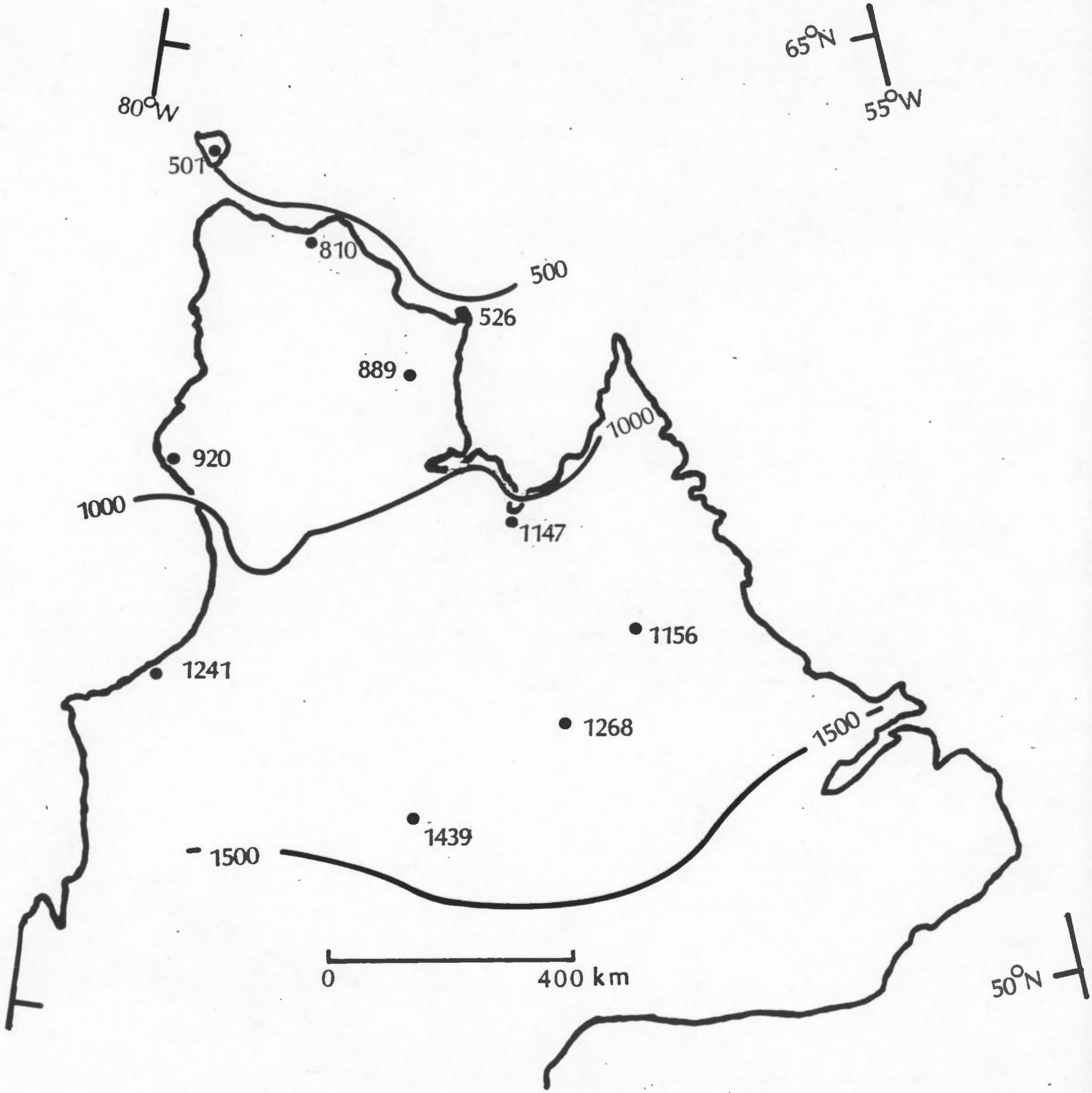


FIGURE 6: THAWING INDEX FOR UNGAVA, IN MEAN ANNUAL °C/DAYS ABOVE 0°C DURING THE PERIOD 1951-1980. Isolines and values at screen leve at specific locations are shown.

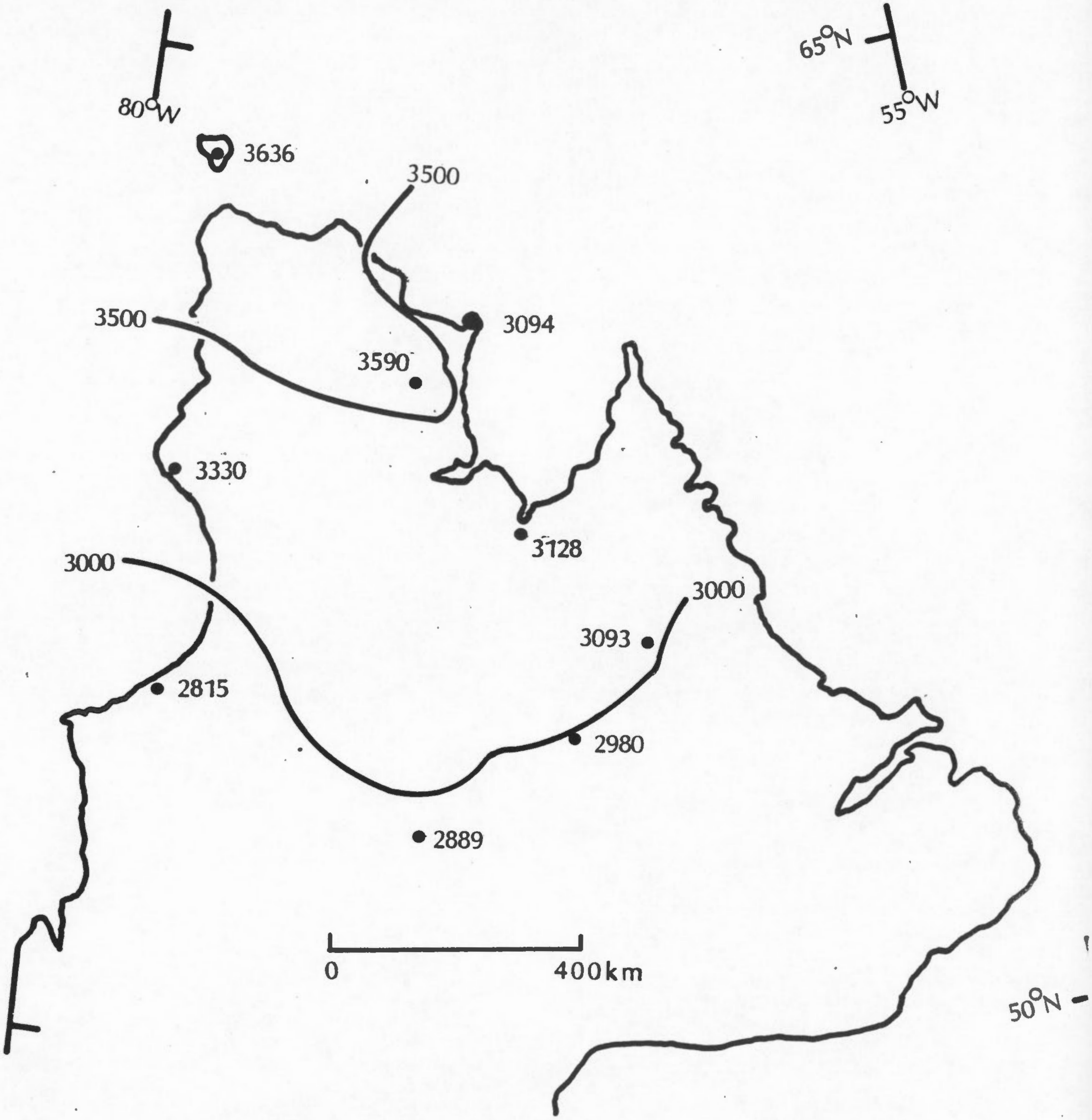


FIGURE 7: FREEZING INDEX FOR UNGAVA, IN MEAN ANNUAL °C/DAYS ABOVE 0°C DURING THE PERIOD 1951-1980. Isolines and screenlevel value at specific locations are shown.

CHAPTER 3: SNOW COVER DATA

Snow-fall distribution in Ungava - spatial and temporal variability

Mean annual snow-fall as well as extreme values are listed in Table 7 for Ungava and the peripheral areas. Figure 8 shows the distribution of mean annual snow-fall across the Peninsula. It is immediately evident that there is a pronounced south east to north west gradient, values declining from 300-350 cm in the Schefferville - Nitchequon sector of the Labrador - Ungava plateau to 150 - 200 cm in the Ungava Peninsula. It is possible that snow-fall values for the interior of the Ungava Peninsula are much lower than 150 cm but no data is available from this region. The hilly part of the plateau in the Purtuniq to Kangiqsuk region, along the Hudson strait coast, associated with the mineralised fold belt of the Labrador geosyncline, may be characterised by locally higher snow-fall values due to its altitude and maritime situation, (at least prior to freeze-up in December).

Figure 9 does not reveal any significant long term trends in snow-fall at the various stations. Year to year variability is very high as can be seen in the extreme values in Table 7. The detailed records show that year to year trends are not necessarily repeated from one station to another throughout the region. The very high Schefferville values for the decade 1970-1980 seem to be anomalous and cannot be explained for the moment. Perhaps the snow gauge was changed when management of the station was changed in 1970.

Snow-pack thickness and duration

Snow-fall values only give a very indirect measure of the effect of snow cover on the thermal regime. The mean thickness and duration of the snow pack may give a better idea of the thermal insulation provided to the ground by the snow cover, although this may be debateable in view of the extreme local variations due to topography, surface vegetation cover

TABLE 7: SNOW-FALL DATA FOR UNGAVA FOR 1951 - 1980

SITE	MEAN ANNUAL SNOW-FALL cm	EXTREME MAXIMUM cm	EXTREME MINIMUM cm
Nitchequon	296	417	129
Schefferville	387	479	213
Kuujuaraapik	241	479	102
Indian House Lake	244	494	68
Fort Mackenzie *	163	288	107
Kuujjuaq	245	480	109
Inukjuak	144	354	57
Kangiqsuk River	207	221	130
Cape Hope's Advance/ Koartaq	151	265	58
Baie de Déception	218	-	-
Nottingham Island	150	327	57

* Normalised for 1941-1970.

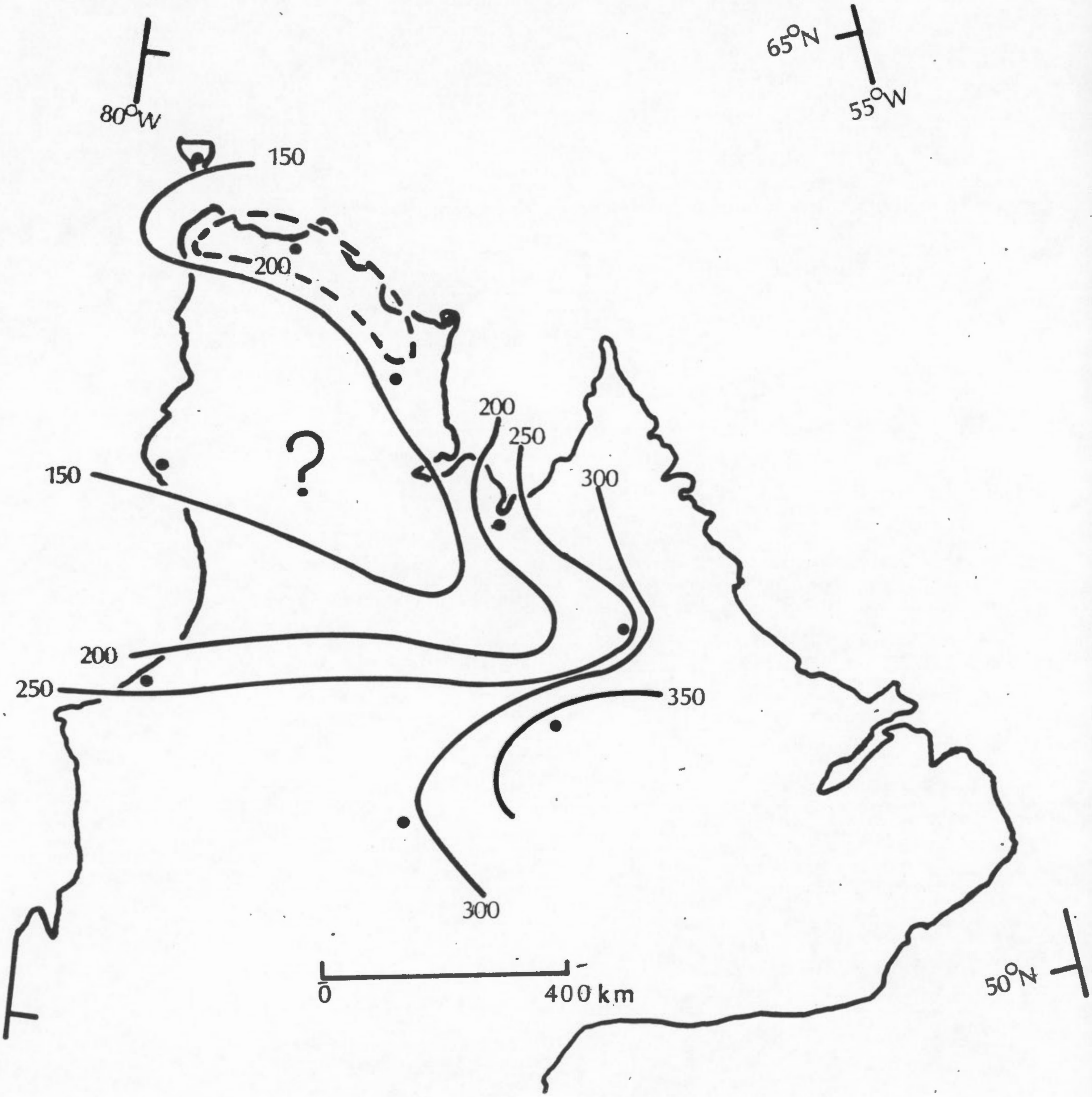
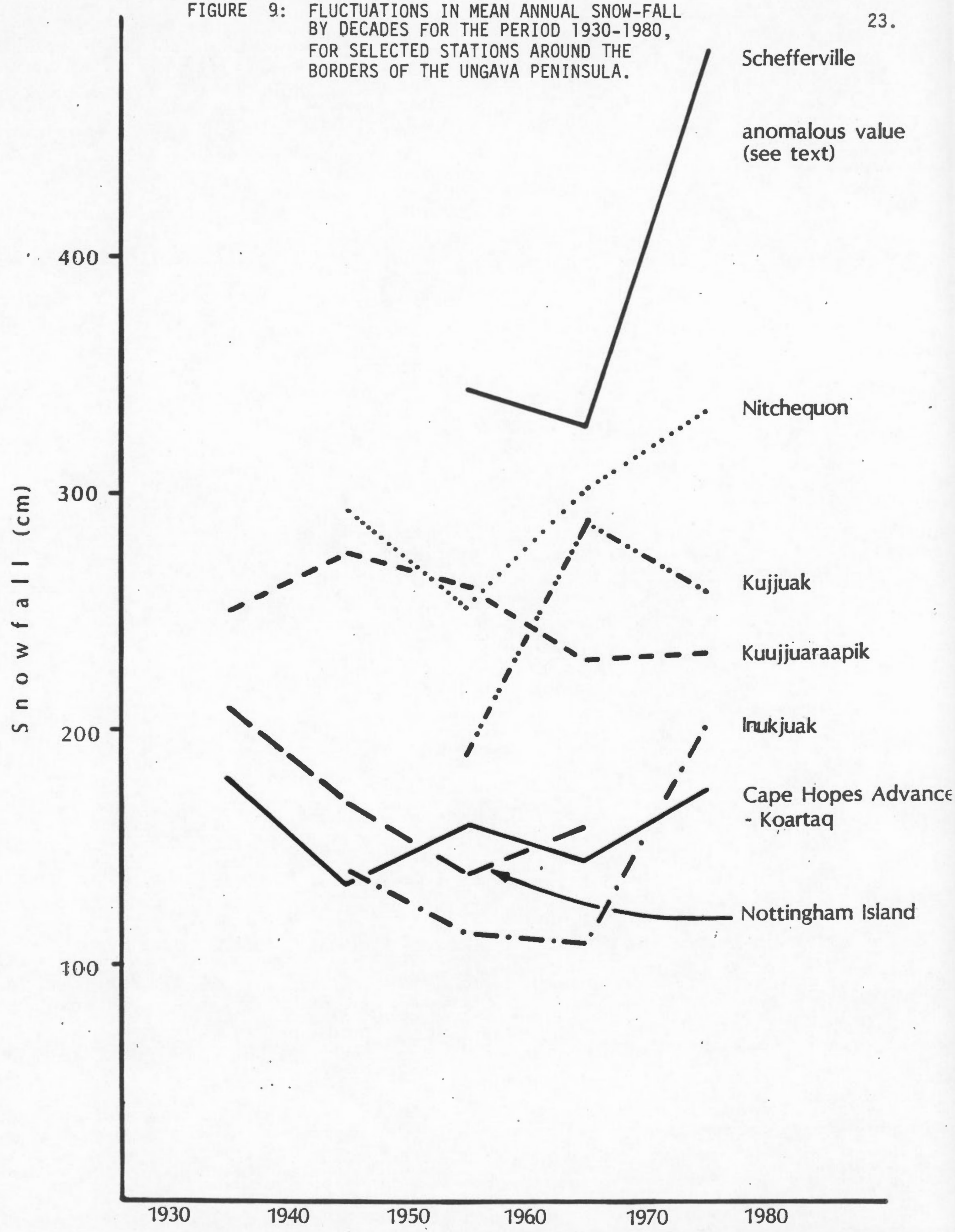


FIGURE 8: MEAN ANNUAL SNOW-FALL DISTRIBUTION (in cm) FOR UNGAVA. Black dots indicate sites, whose snow-fall values were used in the construction of the isolines.

FIGURE 9: FLUCTUATIONS IN MEAN ANNUAL SNOW-FALL BY DECADES FOR THE PERIOD 1930-1980, FOR SELECTED STATIONS AROUND THE BORDERS OF THE UNGAVA PENINSULA.



and aspect. In view of these variations it is extremely important that mean values for each location be compiled from multiple snow course values representative of the main terrain types. The data in Table 8 lists data for 10 stake snow courses located in the vicinity of first order meteorological stations in the Peninsula. The maximum snow pack depths averaged for the nine year period 1970-1979 show average values of 77-80 cm for the Schefferville Nitchequon areas, declining to 50 cm in the Kuujjuaq area and to 30-35 cm on the Hudson Bay coast. A locally high value occurs at Cape Hope's Advance/Koartaq on the Ungava Bay coast; perhaps related to very high late fall-early winter snow-falls.

A spring snow survey in 1977 in the Tasuijaq (Leaf Bay) sector of Ungava led the author of this report to suggest that snow accumulations may be very much less in the Ungava peninsula than in the main Quebec-Labrador Peninsula to the south (Gray et al 1979). With this in mind, Figure 10 was compiled from available snow survey data for the entire Quebec-Labrador Peninsula for the snow year 1976-1977. A strong regional gradient is indeed evident. The south eastern part of the Quebec-Labrador plateau in the Churchill River Basin shows snow-pack values in excess of 150 cm. The values diminish northward and westward to 50-100 cm on the James Bay and Southern Hudson Bay coasts, and to 25-50 cm along the southern coast of Ungava Bay. No values are available either for the northern part of the Ungava peninsula, other than for the Koartaq station, or for the Torngat area. Thus tentative isolines only have been drawn through these regions. It is thought quite probable that most of the central interior of the Ungava Peninsula at altitudes of less than 300 m had an average snow cover of less than 25 cm.

The representativity of the one snow year used in the compilation of Figure 10 is worth examining. Table 9 makes a comparison between the snow cover and snow-fall data measured for five first order stations, in 1976-1977, with long term average values. It is evident that 1976-1977 was characterised by excessive snow-fall values at all stations except

TABLE 8: SNOW COVER FOR REGULAR SNOW COURSES IN UNGAVA

FOR PERIOD 1970-71 TO 1978-79.

Station	Max. depth of snow-pack (cm)	Range of values for snow-pack (cm)	Month thick snow-pack attained	Snow cover index (cm/days)	Snow-free season (cover 5cm)
Nitchequon	77	44-113	March-April	10530	Late May- end of October (160 days)
Schefferville	80	74-91	" "	10682	Mid May - late October (164 days)
Kuujjuaraapik	35	24-53	Feb-March	4868	Late May - begin. of November (181 days)
Kuujjuaq	56	31-79	Mar. April	7594	Late May - end of October (164 days)
Inukjuak	30	15-49	" "	4394	End of May -end of October (158 days)
Cape Hope's Advance /Koartaq	82	59-119	April	11077	Mid June - end of October (140 days)

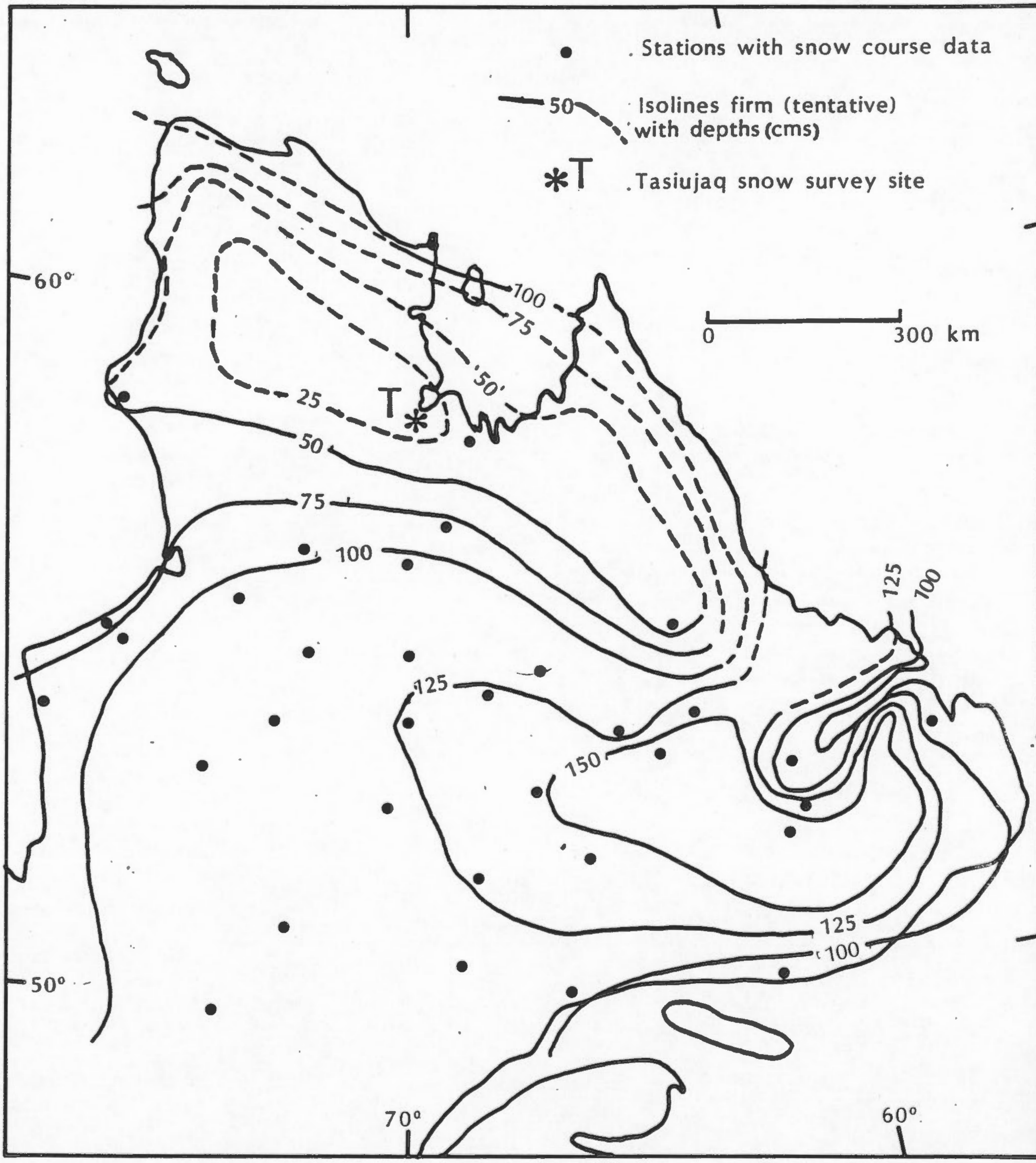


FIGURE 10 ISCLINES ON MAXIMUM SNCW DEPTHS (IN CMS) FOR LABRADOR UNGAVA SNOW COURSES DURING THE WINTER OF 1976-1977.

TABLE 9: COMPARISON OF SNOW COVER AND SNOW-FALL DATA IN UNGAVA FOR 1976-1977 WITH LONG TERM AVERAGES.

	Max. snow depth (cm) 1976-1977	Departure from 1970-1979 mean value (cms)	Snow-fall total 1976-77 (cms)	Departure from 1970-1979 mean values (cms)
Nitchequon	94	+17	465	+141
Kuujjuaraapik	53	+18	259	+41
Kuujjuaq	46	-10	254	-3
Inukjuak	49	+19	227	+34
Koartaq	119	+38	224	+88

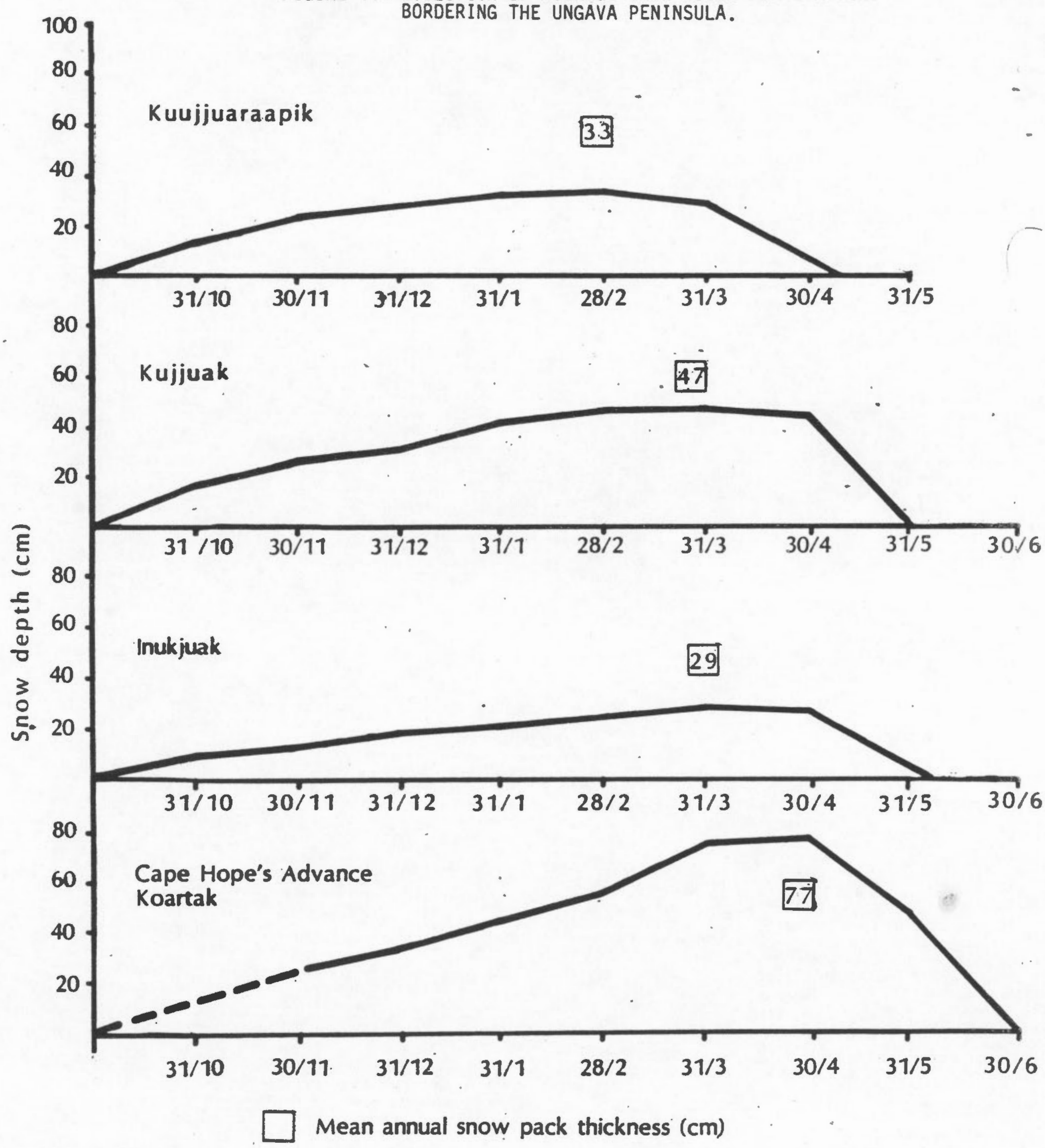
Kuujjuaq where snow-fall was average. Snow depths were above average by 17-38 cm for all stations, again with the exception of Kuujjuaq where snow depth was 10 cm below average. In view of the fact that 1976-1977 was a high snow-fall winter average values of less than 25 cm certainly appear to be a realistic expectation for most of the interior Ungava Peninsula, an expectation remaining to be proved or disproved, however.

Duration of the snow-pack is another factor which contributes to variations in the thermal regime of the ground. Table 8 and Figure 11 show the average build-up and disappearance of the snow-pack at four first order stations throught the snow year. Build-up of snow cover is relatively continuous until a plateau is reached in January-February for the southernmost stations Kuujjuaraapik and Kuujjuaq, in March and April for the northern stations of Inukjuak and Cape Hope's Advance/Koartaq. In the spring,the snow-pack rapidly declines and disappears over a four to six week period. The average snow-free season varies from 140 days at Koartaq up to 180 days at Kuujjuaarapik the difference being mainly related to latitudinal contrasts in heat balance. Schefferville and Nitchequon on the Quebec-Labrador plateau at ~ 500 m elevation show intermediate values of 160-164 days. They are at a similar latitude to Kuujjuaraapik but are characterised by a much thicker snow-pack which is retained about three weeks longer, each year. Of course in each area where topographic conditions permit, snow patches may linger until mid or late summer, or may even survive the entire summer to become semi-permanent snow banks. But snow patches are sporadically distributed and very small in lateral dimensions. Therefore their overall effect on the ground heat flux is strictly minimal both in a spatial and a vertical sense.

Concept of a snow cover index

The concept of a snow cover index, which links together snow-pack depth and duration is not new to ground temperature studies in Quebec-Labrador. Such an index, expressed in cm/days has previously been employed by Annersten (1964) and Nicholson (1978, 1979) in permafrost studies in the Schefferville area of Québec-Labrador. It appears to

FIGURE 11 : EVOLUTION OF AVERAGE SNOW COVER FOR STATIONS BORDERING THE UNGAVA PENINSULA.



represent a valuable overall index of the annual insulative potential of the snow cover whose average value can easily be determined for the meteorological stations in the region (Table 8). A significant contrast is revealed between the Schefferville and Nitchequon high plateau, with a snow cover index of 10,000 - 11,000 cm/days, and the Hudson Bay coast with a snow cover index of only 4,000 - 5,000 cm/days. The Kujjuaq area on the southern coast of Ungava Bay has an intermediate value of ~7,500 cm/days. The Koartaq area on the north-west coast of Ungava Bay has values similar to these at Schefferville and Nitchequon, due in part to moderately high snow-fall values and in part to the late melt of the snow-pack.

CHAPTER 4: PRINCIPAL CONCLUSIONS

Base data on air and ground temperatures and on snow cover characteristics in Ungava have been presented in the context of a) spatial and b) temporal variability. The data should prove useful input in the context of site studies of thermal regimes of the permafrost and active layers in the Ungava Peninsula. The maps of air temperatures and snow cover show major regional trends, towards relatively low values for the interior of the Ungava Peninsula, although it must be stressed that data is almost exclusively available from peripheral stations in this region. The low temperature and low general snow cover suggested for the peninsula indicate permafrost thicknesses for the Ungava Peninsula intermediate between the 200 m depths found on the south eastern margins of the Peninsula (Gray et al (1979), and the 600 m depths inferred for the Purtuniq area on the high Ungava plateau near the northern coast of the Peninsula (Taylor and Judge, 1979).

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