THE RELATIONSHIP BETWEEN METEOROLOGICAL FACTORS AND ICE CONDITIONS IN HUDSON BAY

By

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ABSTRACT

This study focuses on the relationship between ice cover and wind frequency, wind speed and air temperature. Results showed that there are four distinct MELT periods along the west coast of Hudson Bay. With a standardized MELT period, stations are generally higher correlated with their southern neighbours. Onshore wind frequencies increased signficantly from the NOMELT to the MELT period, and were associated with air temperatures 3 to 4 ^{o}C colder than those of offshore winds.

Mean air temperature was most highly correlated with percent ice cover. Ice cover was most strongly correlated with mean air temperature at Chesterfield Inlet and least so at Churchill. Thus, freeze-up and melt at Chesterfield Inlet are most strongly influenced by air temperature whereas at Churchill, other factors, presumably wind direction and currents, strongly influence the ice cover. Ice cover was most strongly influenced by air temperature during the NOMELT period. This shows that cold temperatures hasten freezeback more than warm temperatures hasten MELT.

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Inexpressible gratitude goes to my wife Rita, whose many hours spent on the tables and typing of this thesis made it possible to meet the deadline. I would also like to thank her for her encouragement while patiently supporting me in the pursuit of my studies and her endurance of the n-1 hours that I spent at McMaster for the past few years and the summers that I spend in Churchill, Manitoba.

Last but not least, I would like to thank Ron Schroeder (a.k.a. M-Dog) who didn't directly contribute to this thesis but whose companionship during the "early" hours of many mornings was greatly appreciated and who was around when I needed a well-deserved break with the suggestion of "Munch-Man".

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1.0 INTRODUCTION

Hudson Bay (see Figure 1) is one of the world's unique inland bodies of water. Even though it reaches southwards into relatively middle latitudes, it is still the largest body of water in the world that freezes over completely in the winter and returns to a totally ice free condition in summer. The ice cover has the notable distinction of being one of the factors responsible for the Hudson Bay Lowlands representing the southern most extension of permafrost in the Northern Hemisphere.

Sea ice may play a major role in climate change. Sea ice has a great potential for positive feedback and many numerical models study air-sea-ice interactions with sea ice playing a central role in the response of the models. Air temperature variability has been attributed to sea ice variability as has patterns of atmospheric fluctuations.

This study will examine the sea ice cover variability of Hudson Bay and also, what type of local associations between the ice cover and wind frequency, wind speed and air temperature can be made for Chesterfield Inlet, Churchill and Moosonee.

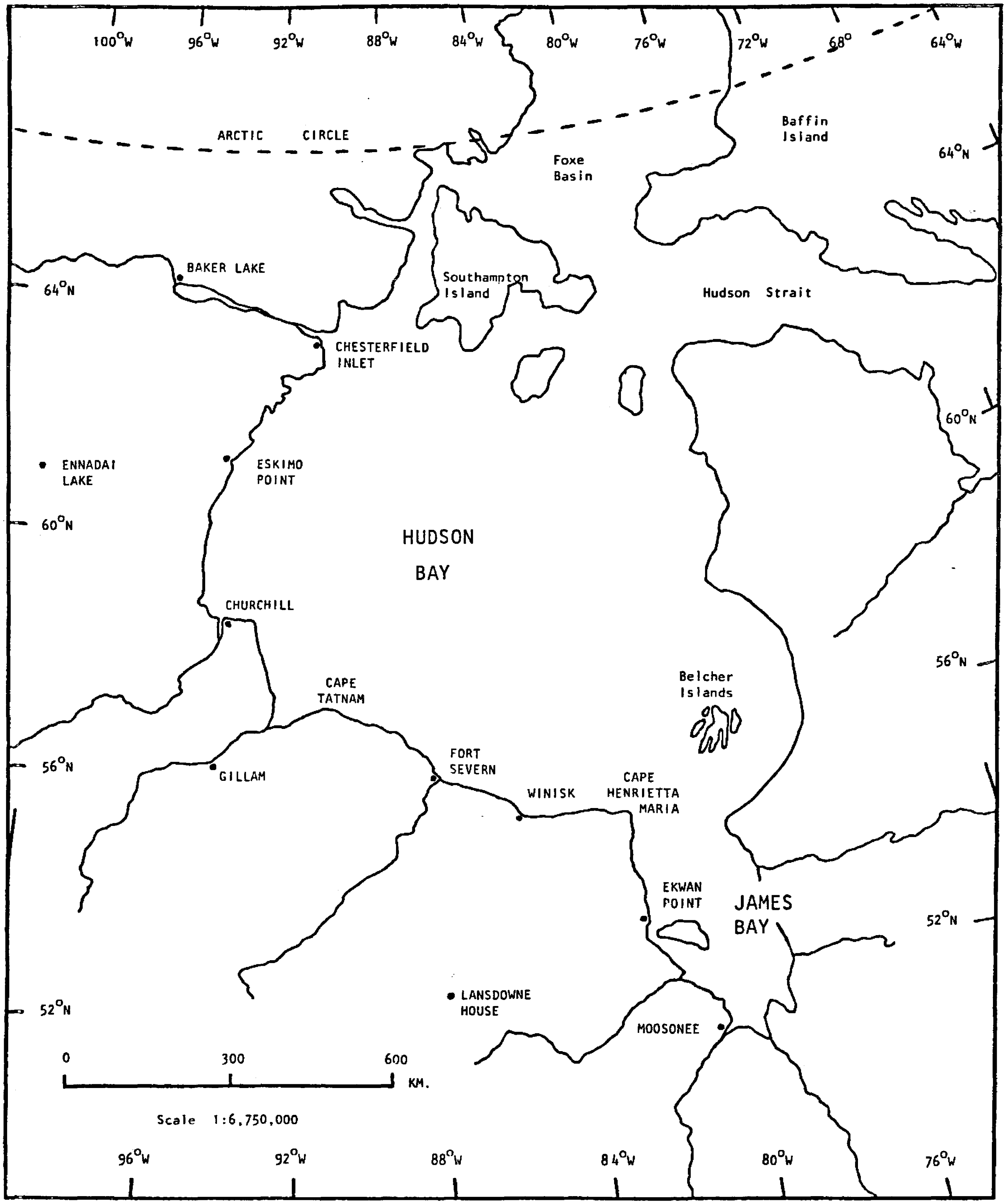

FIGURE 1: General Map of Hudson Bay

1.1 Previous Work

Scientific studies of Hudson Bay only began in the late 1940's. Work began with Burbidge (1949) and Hare (1950) whose studies on Hudson Bay meteorology are still widely used. Barber (1967) is responsible for most of the oceanographic information on Hudson Bay. Aspects of Hudson Bay's heat budget have been investigated by Schwerdtfeger (1962), Morrissey (1964) and Barber (1967). Danielson (1969) investigated the temporal and spatial variations of the components of the heat budget of Hudson Bay and was the first to quantify available sea ice data and published semi-monthly ice concentration maps of Hudson Bay.

Recently, Prinsenberg (1980, 1983) has been studying the effect of hydroelectric developments on freshwater input rates in Hudson and James Bays. He has been using a one-dimensional mixed-layer model to study the relative importance of the run-off and ice cover on the seasonal pattern of the pycnocline and sensitivity of Hudson Bay to their variations.

Rouse and Bello (1983) have done some initial work on the advective influences of Hudson and James Bays on the climate of the surrounding Hudson Bay Lowlands. They analyzed long-term meteorological data by trend surface analysis to show that Hudson and James Bays do exert strong cooling effects on the Lowlands. The cooling effect was directly attributable to the longevity of offshore sea ice and the small advective heat input of the cold onshore winds. More recently Rouse (1984) has been considering the importance of wind direction and of regional advection on the surface energy budget and seasonal evaporation patterns in the Hudson Bay Lowlands.

Relationships between ice conditions and meteorological factors have also been investigated elsewhere. Results of a 12 year study by Konishi and Saito (1972) showed that ice in the Bering Sea was influenced by changes occurring in sea currents and weather conditions in cycles of two years. He found, also, that the distribution of ice exerted an influence on the course of atmospheric pressure and air temperature. Rogers (1978) reported that air temperature, in the form of thawing degree days was the parameter most highly correlated with the summer ice margin distance at Barrow, Alaska. The ice margin distance was also highly correlated with wind direction and sea level pressure.

2. DATA

The Atmospheric Environment Service (AES) has been conducting a comprehensive ice reconnaisance and ice forecasting program in Hudson Bay since 1959. Aerial ice observations together with meteorological, oceanographic and satellite data are used to produce the composite records of ice behaviour from the period of break-up to freeze-back. The data for the years 1971 to 1973 was taken from the yearly publications of "Ice Summary and Analysis: Hudson Bay and Approaches" which are prepared by the Ice Branch of AES in Ottawa. The data for 1974 to 1981 came directly from the photostat copies of the weekly composite ice charts prepared by the AES division of Ice Forecasting Central in Ottawa.

Ice cover conditions were averaged for an area within a 150 kilometre radius from each coastal station. The weekly figures, in percentage of ice cover, were then averaged into the semi-monthly values used in the later analyses. For the purpose of this study, ice conditions were grouped into two categories. The first is termed as the MELT season which extends from the last 1/2 month that a station had 100% ice cover to the first 1/2 month the station experienced 0% ice cover. The second category is the NOMELT season which encompasses the rest of the ice year. MELT roughly represents the category of Spring as proposed by Danielson (1971) in which ice cover is dissipating during May to mid-August. NOMELT represents his definition of Summer, Autumn and Winter categories.

Meteorological data came from Class A meteorological stations which are located at airports. Air temperature and wind direction are collected hourly for 24 hour periods. Wind speed is collected on a continuous wind-kilometre run basis. These three meteorological parameters were then averaged into the same semi-monthly periods as was the ice data.

3. RESULTS AND DISCUSSION

3.1 Ice Conditions

Ice conditions can be grouped into four distinct categories:

Total Ice Cover : 100%, from late January to late April/early May;

Break-up (MELT) : 100% to 0%, from late April/early May to late July/early August;

No Ice Cover : 0%, from August to late October;

Freeze-up : 0% to 100%, from early November to early January.

Ice conditions are static during total ice cover and of course when there is no ice. Dynamic ice conditions are experienced during break-up and freeze-up.

Due to many spatial and temporal influences, break-up in Hudson and James Bays occurs at varying times. Table 1 shows the semi-monthly ice coverage for stations along the "west" coast of Hudson Bay. In this report, the "west" coast of Hudson Bay refers to the west and south coast of Hudson Bay and the west coast of James Bay. This data closely agrees with the semi-monthly ice concentration maps of Danielson (1971).

Break-up occurs earliest at the four most southerly stations, Winisk, Cape Henrietta Maria, Ekwan Point and Moosonee. Throughout the rest of the MELT season ice conditions at Chesterfield Inlet are almost identical to ice conditions in James Bay. A continual dissipation in

Month	Ic1	Ic2	Ic3	Ic4	Ic5	Ic6	Ic7	Ic8	Ic9
Jan	88	96	99	98	98	98	93	95	95
	100	100	100	100	100	100	100	100	100
Feb	100	100	100	100	100	100	100	100	100
	100	100	100	100	100	100	100	100	100
Mar	100	100	100	100	100	100	100	100	100
	100	100	100	100	100	100	100	100	100
Apr	100	100	100	100	100	100	100	100	100
	100	100	100	100	100	100	100	100	100
May	100	100	100	100	100	99	99	97	99
	80	94	97	97	96	93	90	78	87
June	55	86	89	91	91	83	74	57	63
	36	61	86	79	79	72	63	34	35
July	14	28	61	56	61	51	35	11	12
	4	4	22	29	30	24	16	0	0
Aug	0	0	4	4	5	7	3	0	0
	0	0	0	0	0	0	0	0	0
Sept	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0
Oct	0	0	0	0	0	0	0	0	0
	1	1	0	0	0	0	0	0	0
Nov	8	6	4	1	0	1	0	0	0
	25	12	11	12	4	8	3	1	0
Dec	36	30	34	34	26	30	22	19	18
	61	68	80	82	80	77	61	63	62

Ic1 = Chesterfield Inlet
Ic2 = Eskimo Point
Ic3 = Churchill
Ic4 = Cape Tatnam
Ic5 = Fort Severn
Ic6 = Winisk
Ic7 = Cape Henrietta Maria
Ic8 = Ekwan Point
Ic9 = Moosonee

TABLE 1: Mean semi-monthly ice concentrations (%) along the west coast of Hudson Bay for the years, 1970-1981.

ice cover throughout the MELT season occurs both southwards from Chesterfield Inlet and northwards from James Bay. By early August this leads to offshore ice existing only in the zone from Churchill southeastward to Cape Henrietta Maria. The ice exists here due to the persistence of northwesterly winds and the counter-clockwise current of Hudson Bay. A more detailed discussion of ice conditions and factors causing change in ice concentrations may be found in reports by Danielson (1969, 1971).

The nine stations in Table 1 can be divided up into 4 distinct groups based on their MELT seasons. Chesterfield Inlet and Eskimo Point have a MELT season that extends from eary May to early August. Churchill, Cape Tatnam and Fort Severn have a season which extends two weeks later to late August. Winisk and Cape Henrietta Maria have their MELT season from late April to late August while Ekwan Point and Moosonee have theirs from late April to late July.

The shortest MELT season (3 1/2 months) occurs both in the most northerly and most southerly groups. The longest MELT season (4 1/2 months) occurs at Winisk and Cape Henrietta Maria. This agrees with all previous work done in Hudson Bay. Thus, even though this area is one of the first to break-up it is the last to display offshore ice.

By standardizing the MELT season from late April to late August for all nine stations, it is possible to see which stations resemble one another. Late April to late August is the longest MELT season experienced by any one station and will therefore include all other stations. Table 2 shows the correlation coefficients for all the coastal stations in this study. Generally the stations are most highly correlated with their southern neighbours. Chesterfield Inlet is correlated with Eskimo Point, Eskimo Point with Churchill, Churchill with Cape Tatnam and Cape Tatnam with Fort Severn. Fort Severn and Winisk are most highly correlated with each other. Cape Henrietta Maria is surprisingly correlated with Moosonee whereas Ekwan Point and Moosonee are correlated with each other.

3.2 **Wind**

Figures 2, 3 and 4 show the wind frequency and wind speeds by wind direction for Chesterfield Inlet, Churchill and Moosonee. All changes in mean frequency and mean wind speed discussed in this section are significant at the 98% confidence level using a two tailed **t**-test. Changes from the NOMELT to MELT season are as follows. At Chesterfield Inlet, there was a decrease in both frequency and wind speed fom the northwesterly sectors. Also, onshore winds signficantly increased in frequency from one season to another. At Churchill, there was a decrease in wind frequency from the westerly sectors and an increase from the onshore sectors. At Moosonee, wind frequencies decreased from the westerly sectors and increased from the onshore sectors. Wind speeds decreased from the northwesterly sectors and increased from both the onshore and southwesterly sectors.

	Chesterfield	Eskimo	Church	Tatnam	Severn	Winisk	Maria	Ekwan
Eskimo	.902							
Church	.812	.914						
Tatnam	.819	.912	.974					
Severn	.779	.889	.941	.975				
Winisk	.805	.896	.924	.954	.979			
Maria	.832	.903	.901	.918	.911	.916		
Ekwan	.854	.884	.814	.833	.826	.834	.925	
Moose	.872	.892	.829	.856	.845	.856	.940	.984

Table 2: Correlation coefficients between coastal stations for the standardized MELT period of late April to late August.
All correlation coefficients are signficant at the 99% confidence level.

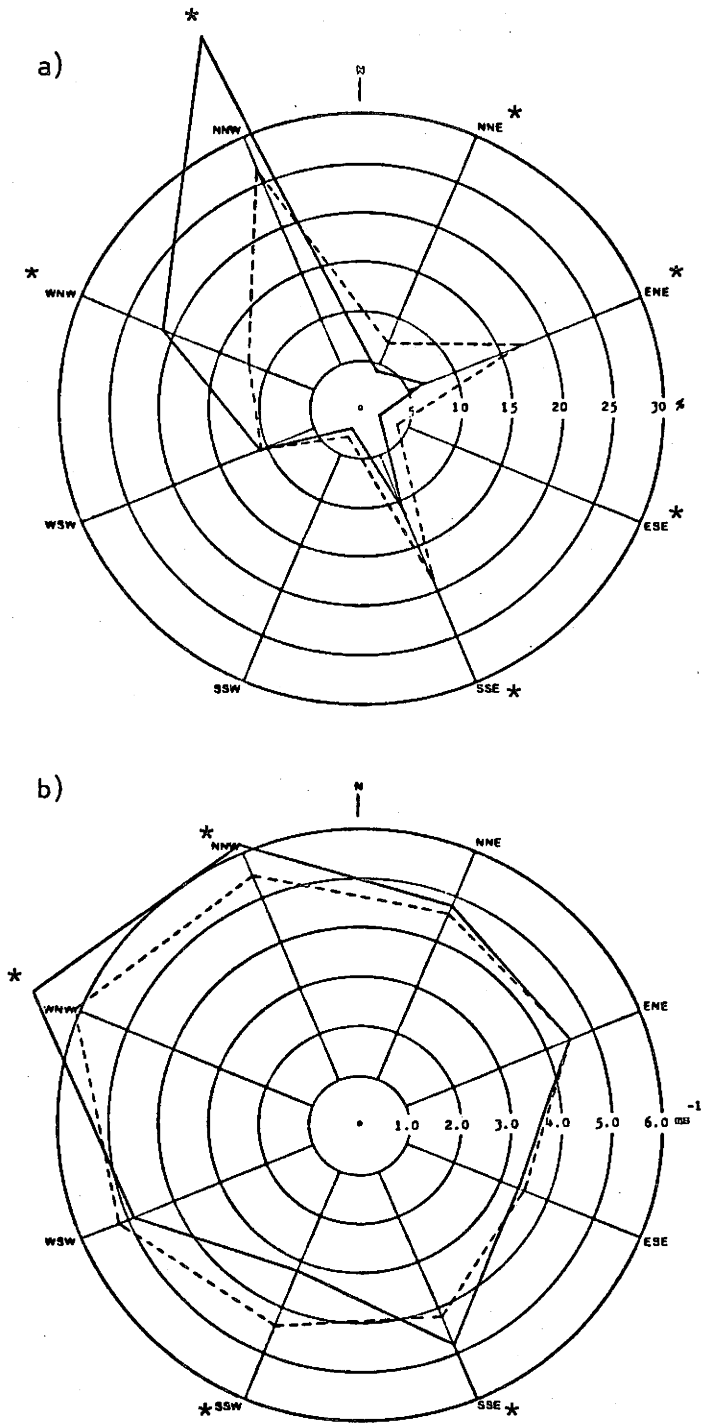

FIGURE 2: a) Wind frequency and b) Wind speed by wind direction for NOMELT —— and MELT --- for Chesterfield Inlet, 1972-1980.

* indicates a significant difference between means (98% confidence level)

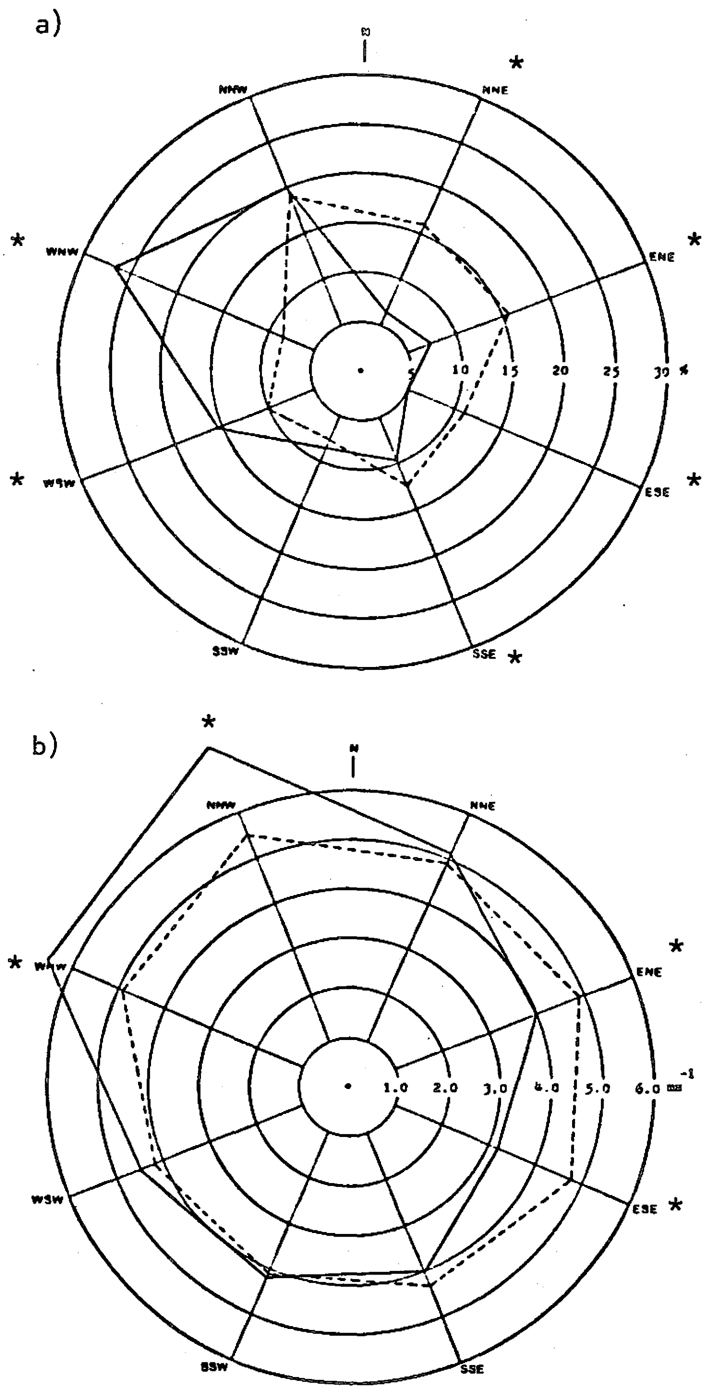

FIGURE 3: a) Wind frequency and b) Wind speed by wind direction for NOMELT —— and MELT --- for Churchill, 1972-1980.

* indicates a significant difference between means (98% confidence level)

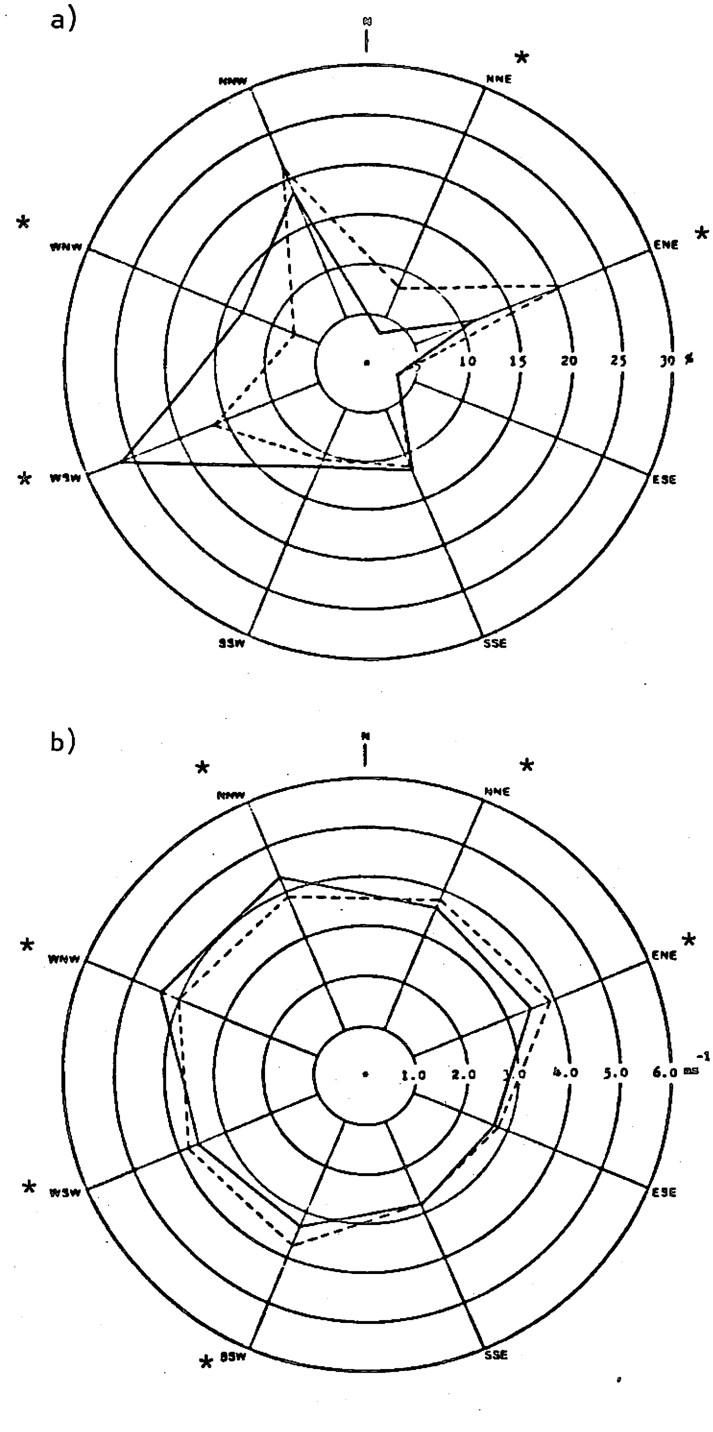

FIGURE 4: a) Wind frequency and b) Wind speed by wind direction for NOMELT ——— and MELT - - - for Moosonee, 1972-1980.

* indicates a significant difference between means (98% confidence level)

The three stations on the coast experience similar wind frequencies to those of inland stations for the entire year. Figure 5 shows the frequency of wind by direction for Baker Lake and Chesterfield Inlet. Figure 6 represents the average of Ennadai Lake and Gillam matched with Churchill and Figure 7 shows Lansdowne House and Moosonee. It is evident that the coastal stations and their matched inland stations are under the influence of the same regional High and Low pressure centres since they experience similar directional frequencies and wind speeds.

During the NOMELT season the dominant High pressure system is located over the central Northwest Territories. The winds blowing out of this system are from the NNW by the time they reach the coast of Hudson Bay. Thus, Chesterfield Inlet and Churchill exhibit the dominance of winds from the NNW sector. Moosonee at this time, is influenced by a more westerly wind pattern. One explanation for this could be the increase in surface roughness. As surface winds blow from the northwest off the tundra and onto forest, the surface roughness increases and the winds will cross the isobars at a greater angle. In addition, Moosonee is located in the high mid-latitudes and is more influenced by cyclonic storm systems in the winter period than the more northerly stations.

Although the dominant High moves northwards into the western Canadian Arctic Archipelego during the MELT season, the dominance of the Arctic air mass is still felt. There still is a dominant NNW wind

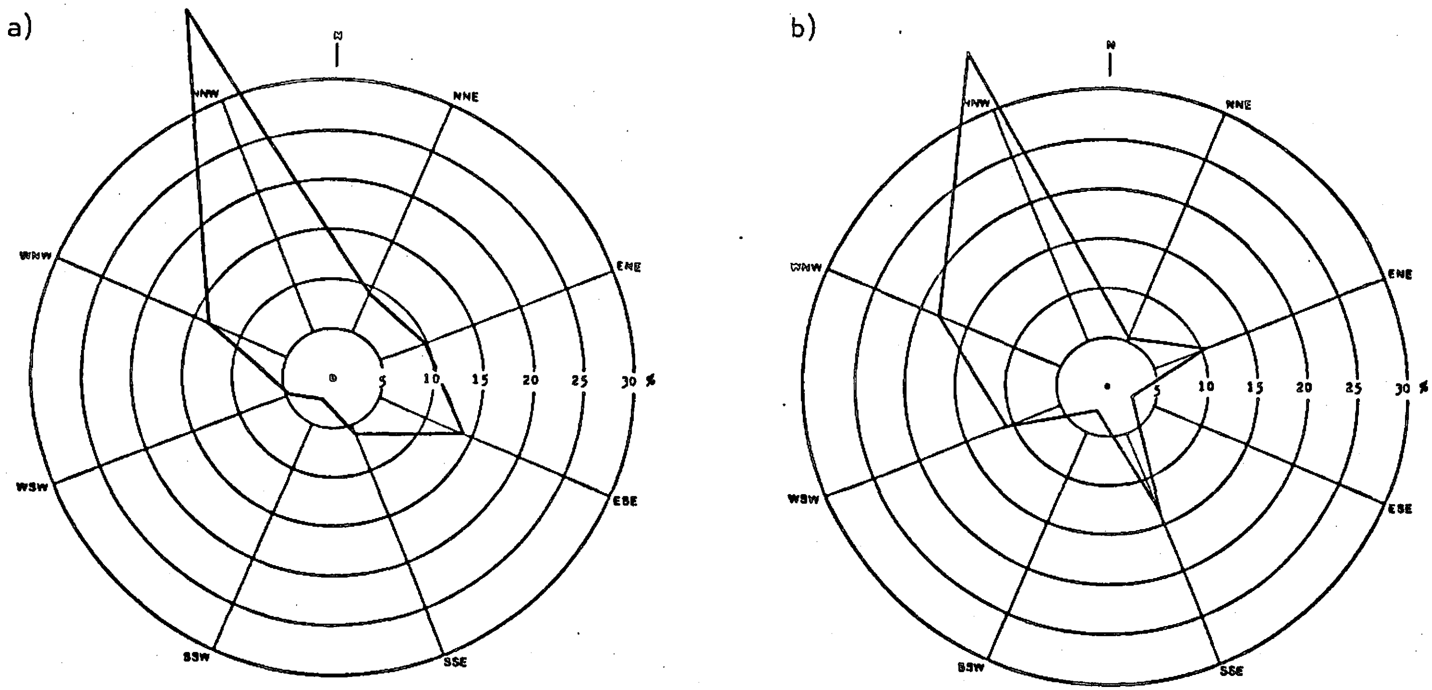

FIGURE 5: Wind frequency by wind direction for a) Baker Lake and b) Chesterfield Inlet for the years 1972-1980.

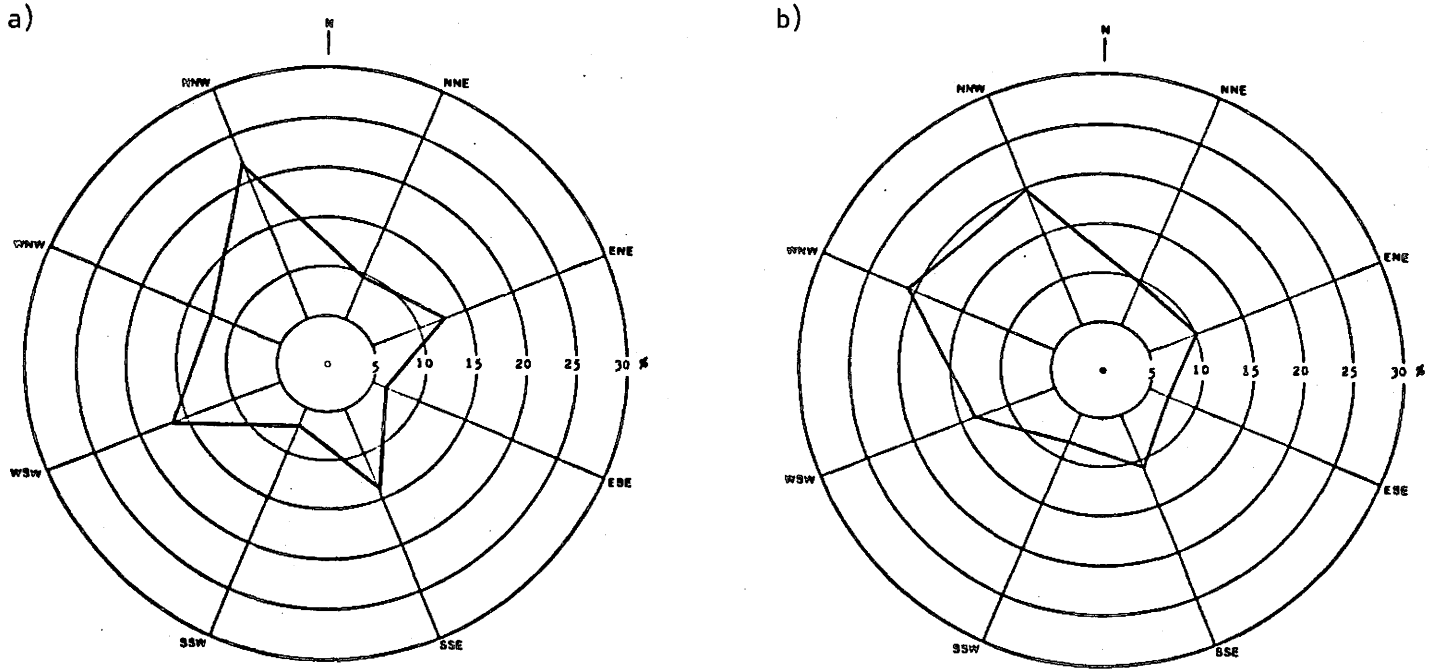

FIGURE 6: Wind frequency by wind direction for a) average of Ennadai Lake and Gillam and b) Churchill for the years 1972-1980.

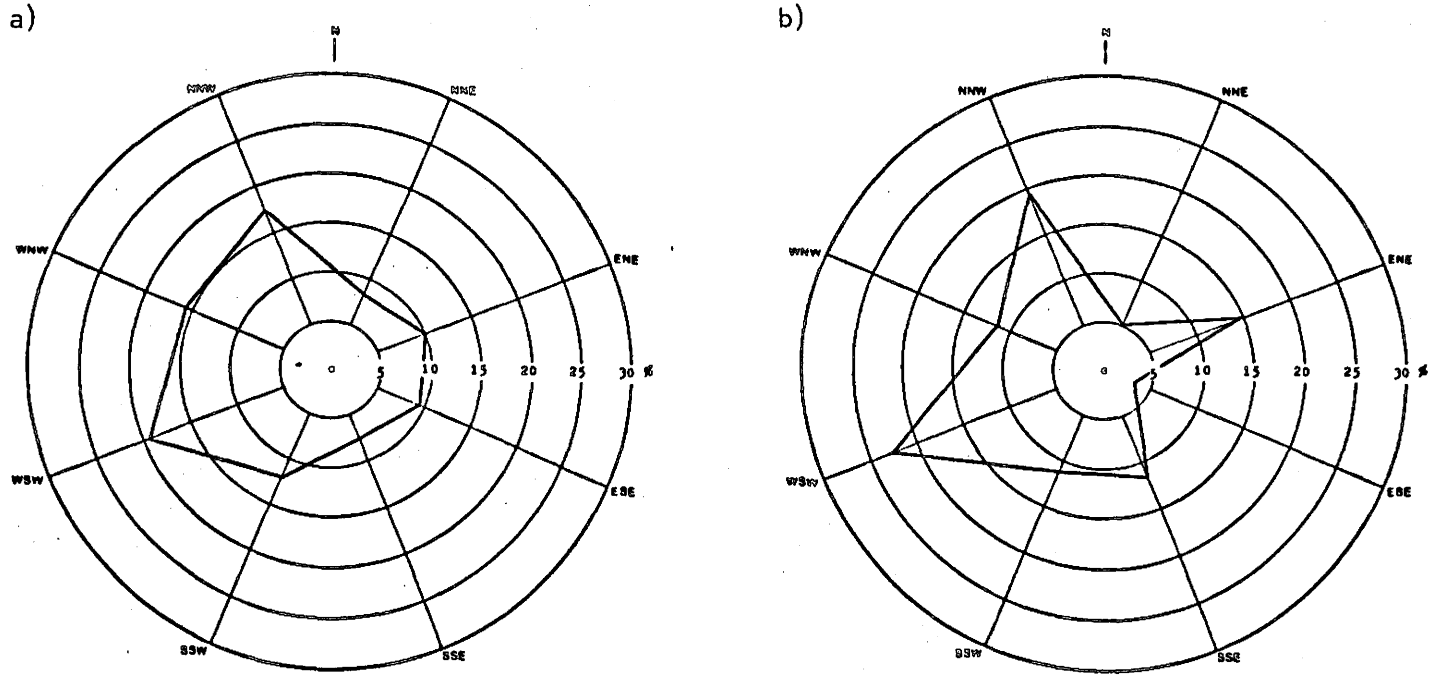

FIGURE 7: Wind frequency by wind direction for a) Lansdowne House and b) Moosonee for the years 1972-1980.

at both Chesterfield Inlet and Churchill although it is of lesser frequency than in the NOMELT period.

It can also be shown conclusively that there is a significant increase in onshore winds from the NOMELT to MELT seasons. During MELT, winds from the onshore sector are more frequent than those from offshore at all three stations. Although the frequency of onshore winds did increase, there was no significant change in onshore windspeeds. It should also be noted that mean windspeeds from the northwesterly sectors significantly decreased at all three stations from NOMELT to MELT.

3.3 Combined Wind and Temperature Effects

Danielson (1969) stated that during the period from May to July, Hudson Bay develops and intensifies its role as a cooling agent. The coldest air temperatures during MELT are linked with onshore winds blowing over the pack ice. Tables 3, 4 and 5 show the semi-monthly surface air temperature by wind direction. The coldest air temperatures are associated with onshore winds during each station's respective MELT season, and warmest air temperatures are associated with offshore winds.

During the NOMELT season, Hudson Bay supplies the air with substantial amounts of heat (Danielson, 1969) and stands out as a heat

Azim.	Jan		Feb		Mar		April		May		June		July		Aug		Sept		Oct		Nov		Dec	
NNE	-25.4	-19.8	-25.2	-21.8	-22.1	-19.4	-14.7	-11.6	-5.0	-1.7	0.5	4.3	5.6	7.8	7.5	6.9	4.4	-0.5	-3.7	-5.2	-10.0	-13.9	-20.6	-18.7
ENE	-23.1	-21.1	-22.1	-18.3w	-18.9	-15.6w	-10.6	-7.9	-3.1w	-1.4	1.1	3.0c	5.1	7.1c	7.5	6.4	4.3	1.4	-0.8	-1.7w	-7.1	-11.8	-15.3	-16.3w
ESE	-22.2w	-19.6w	-19.1w	-22.9	-16.2w	-16.8	-10.5w	-7.3w	-3.4	-0.9	1.5	3.1	4.9c	7.2	7.0c	6.1c	4.4	2.2	-0.4w	-2.4	-5.4w	-10.0w	-14.9w	-17.1
SSE	-25.5	-20.9	-20.6	-22.2	-19.4	-17.4	-12.0	-8.7	-4.1	-0.7	1.0	4.9	6.6	9.2	8.4	7.0	5.3	3.5w	-0.4w	-2.4	-6.5	-12.3	-21.0	-18.1
SSW	-30.9	-23.0	-21.9	-23.7	-27.3	-19.5	-16.4	-9.0	-5.8	0.9w	1.4	8.0	12.3	13.0w	12.9w	8.5w	7.2w	3.4	-2.2	-6.5	-12.9	-20.4	-22.8	-19.7
WSW	-31.6	-30.1	-33.4	-33.0	-30.9	-25.7	-21.1	-13.1	-5.5	-0.5	2.3w	8.4w	12.5w	11.4	12.4	7.5	5.5	-0.7	-6.7c	-11.8	-16.4	-25.3	-29.4	-25.3
WNW	-32.8c	-32.2	-36.2c	-34.4c	-32.0c	-28.9c	-24.3c	-17.5c	-8.6	-4.7c	0.3c	6.8	11.2	9.8	9.6	6.6	4.3	-1.8c	-6.3	-14.3c	-18.6c	-28.7c	-31.3c	-31.7c
NNW	-32.4	-34.6c	-31.4	-33.8	-31.5	-27.7	-21.2	-16.4	-9.0c	-2.8	0.9	6.8	9.4	11.4	9.0	6.3	3.3c	-1.3	-6.1	-10.3	-15.3	-21.7	-30.2	-30.2

TABLE 3: Mean semi-monthly surface air temperature (^{o}C) by wind direction for Chesterfield Inlet, 1972-1980. "w" and "c" indicate warmest and coldest temperatures, respectively, for each ½ month.

Azim.	Jan		Feb		Mar		April		May		June		July		Aug		Sept		Oct		Nov		Dec	
NNE	-22.2w	-20.7	-20.4	-19.3	-19.4	-15.2	-12.8	-6.9	-3.2	-0.3c	1.2c	4.4c	8.0	9.1c	9.0c	8.4c	6.3	3.4	1.4	-1.7w	-3.6w	-7.7w	-17.5	-17.2
ENE	-23.0	-16.5w	-19.7	-16.9w	-20.2	-16.5	-10.9	-6.3	-2.9	-0.2	2.0	4.7	8.1	9.5	9.3	9.0	6.5	3.2	2.1w	-1.7w	-3.6w	-8.0	-16.2	-16.5
ESE	-28.1	-23.0	-18.2w	-16.9w	-20.6	-16.1	-10.5	-6.9	-2.2	1.9	4.4	7.7	11.1	12.3	11.2	10.0	5.9	3.1	1.6	-2.7	-4.2	-9.1	-15.8w	-15.8w
SSE	-29.6c	-23.4	-22.8	-20.6	-16.0w	-14.2	-9.0w	-3.6	1.9w	4.7	5.9	11.9	13.1	14.7	12.3	12.2	7.4	4.0	0.1	-2.6	-6.8	-9.8	-19.2	-19.5
SSW	-27.8	-22.6	-23.1	-19.8	-16.4	-11.8w	-9.1	-0.2w	1.9w	5.4	7.7	14.9w	16.7	14.1	13.6	13.9w	8.7w	4.4w	0.6	-2.6	-6.3	-12.7	-20.9	-22.3
WSW	-29.1	-27.5	-30.3c	-24.3	-23.0	-21.1	-13.1	-0.5	1.6	6.0w	8.0w	13.5	16.8w	15.0w	14.4w	13.2	7.3	3.4	-0.3	-4.1	-8.8	-17.4	-26.1	-26.9c
WNW	-29.4	-27.9c	-29.4	-27.5c	-26.0c	-23.0c	-17.6c	-10.3c	-4.9c	1.1	3.9	10.1	12.4	12.2	11.4	10.6	6.3	1.9	-2.5c	-5.4c	-11.2c	-18.3c	-26.6c	-25.7
NNW	-25.1	-22.6	-23.0	-21.9	-21.1	-19.4	-14.6	-8.1	-4.5	0.6	1.7	4.9	7.9c	9.3	9.4	8.6	5.3c	1.8c	-1.9	-5.0	-9.5	-14.4	-21.0	-22.3

TABLE 4: Mean semi-monthly surface air temperature (°C) by wind direction for Churchill, 1972-1980. "w" and "c" indicate warmest and coldest temperatures, respectively, for each ½ month.

Azim.	Jan		Feb		Mar		April		May		June		July		Aug		Sept		Oct		Nov		Dec	
NNE	-20.8	-16.1	-14.1w	-13.6	-11.9	-8.8	-6.0	-0.5	2.6	4.9	-5.7c	10.5	14.4	12.9	13.8	11.6	9.1	5.2	7.3	2.7	-0.6	-5.2	-13.5	-22.1c
ENE	-17.7	-17.5	-17.0	-16.5	-15.0c	-9.3	-5.3	0.4	3.1	9.3	10.3	15.3	15.9	15.6	16.5	15.2	11.1	8.2	6.6	1.9	-0.7	-5.1	-13.4	-16.7
ESE	-15.1w	-14.6w	-17.3	-10.0w	-9.8	-4.7w	-1.7	0.0	5.4	9.5	10.2	14.9	14.7	14.7	15.2	13.2	10.4	8.8	5.3	1.8	1.1	-4.2w	-15.3	-14.2w
SSE	-17.4	-18.7	-16.4	-14.0	-7.4	-4.9	-0.8	3.2	6.5	13.3	15.3	17.4	17.7	17.7	16.8	15.8	12.2	8.6	6.4	2.8	1.2	-6.3	-12.9w	-17.7
SSW	-20.3	-18.9	-14.6	-15.3	-4.9w	-5.8	0.6w	4.9w	9.3w	15.6w	17.3w	19.4	20.0w	19.5w	17.4w	18.3w	13.9w	10.6w	7.6w	4.0w	2.3w	-6.1	-15.8	-15.6
WSW	-23.0c	-23.9c	-22.8c	-15.9	-14.9	-7.3	-5.7	2.7	5.7	13.6	15.2	19.5w	17.6	17.6	16.5	16.2	10.1	7.7	4.7	1.5	-2.8	-8.0c	-19.7c	-19.8
WNW	-21.1	-20.6	-20.0	-17.5	-14.9	-12.4	-8.3c	-0.7	1.6	8.8	8.4	13.0	15.4	15.2	13.0	13.9	8.7	5.0	2.7c	-0.1	-3.1c	-6.0	-15.1	-18.0
NNW	-16.5	-18.1	-20.3	-18.6c	-14.9	-12.5c	-7.9	-1.7c	0.6c	4.7c	5.8	9.2c	11.9c	12.7c	11.2c	11.4c	8.4c	4.9c	2.9	-0.5c	-1.7	-5.4	-13.0	-18.7

TABLE 5: Mean semi-monthly surface air temperature (^{o}C) by wind direction for Moosonee, 1972-1980. "w" and "c" indicate warmest and coldest temperatures, respectively, for each ½ month.

source when compared to the land surface. Warmest air temperatures are now associated with onshore winds. The above patterns do not show up as strongly at Moosonee which may be due to James Bay experiencing different patterns of break-up and freeze-up than does Hudson Bay. The Chesterfield Inlet and Churchill patterns agree closely with those found for the years 1942-1966 by Danielson (1969).

3.4 Correlation Analysis

Correlations between the amount of sea ice cover and the various meteorological parameters previously discussed were analyzed for NOMELT, MELT and the entire year. Table 6 shows the correlation coefficients and the regression equation parameters for mean air temperature as a linear function of percent ice cover at the three stations. All correlation coefficients are statistically significant at the 99% confidence level. The regression equation is of the form:

$$\overline{T} = a + bI \tag{1}$$

where $\overline{T}$ is the mean air temperature (^{o}C) and I is the amount of sea ice cover (%).

The correlation coefficients are always negative and this is as expected where, as (air temperature/ice cover) increases, the (ice cover/air temperature) decreases. At all three stations $\overline{T}$ during the MELT season was the most highly correlated with ice cover, followed by

	r	a	b
Chesterfield			
All Year	-.647	-0.18	-.225
NOMELT	-.731	-7.66	-.204
MELT	-.842	8.51	-.120
Churchill			
All Year	-.465	1.17	-.147
NOMELT	-.664	-4.75	-.168
MELT	-.738	12.20	-.093
Moosonee			
All Year	-.572	6.79	-.166
NOMELT	-.722	1.70	-.181
MELT	-.861	16.40	-.124

Table 6: Correlation coefficients and regression equation parameters between mean air temperature (C) and ice cover (%) for Chesterfield Inlet, Churchill and Moosonee for all year, NOMELT and MELT.
All correlation coefficients are signficant at the 99% confidence level.

the NOMELT period and then the entire year. For the entire year, Chesterfield Inlet had the highest correlation coefficient together with the largest b coefficients. Churchill had the lowest correlation coefficient and the smallest b coefficient. This indicates that at Chesterfield Inlet, ice cover is most strongly correlated with mean air temperature and least so at Churchill. Also, the smallest b coefficients and the highest correlation coefficients occurred during MELT, and the largest b coefficients occurred during NOMELT. This indicates that ice cover is more strongly influenced by mean air temperature during the freeze back interval of the NOMELT period than during MELT.

Next, wind frequency, wind speed and air temperature by wind direction were correlated against ice cover. The highest and most significant correlations were with air temperature, followed by wind frequency and wind speed. The air temperature analysis was done by combining individual sectors into offshore and onshore groups. It was found that the results varied substantially depending upon what sectors were included. Therefore, sectors that contained portions of a coastline were not used. The NNW and SSE sectors at Chesterfield Inlet, the WNW, NNW and ESE sectors at Churchill and the NNW and ESE sectors at Moosonee were not used in this study.

An identical analysis was done as for mean air temperature except in this case the air temperature applied to the average of the sectors comprising the offshore/onshore groups. Table 7 shows the

		r	a	b
Chesterfield				
All Year	On	-.670	1.21	-.180
	Off	-.623	0.42	-.220
NOMELT	On	-.759	-1.07	-.194
	Off	-.727	-3.60	-.230
MELT	On	-.835	6.42	-.084
	Off	-.746	10.60	-.125
Churchill				
All Year	On	-.549	2.40	-.145
	Off	-.404	2.07	-.135
	On	-.694	-1.03	-.161
	Off	-.573	-2.82	-.157
	On	-.817	10.80	-.090
	Off	-.497	14.00	-.060
Moosonee				
All Year	On	-.579	6.74	-.153
	Off	-.531	7.62	-.162
	On	-.676	3.38	-.163
	Off	-.643	3.46	-.173
	On	-.883	15.40	-.105
	Off	-.754	18.40	-.106

TABLE 7: Correlation coefficients and regression equation parameters between onshore and offshore air temperatures (C) and ice cover (%) for Chesterfield Inlet, Churchill and Moosonee for all year, NOMELT and MELT.
All correlation coefficients are signficant at the 99% confidence level.

correlation coefficients (all signficant at the 99% confidence level) and the regression equation parameters. The highest correlation coefficients together with the smallest b coefficients occurred for both the onshore and offshore sectors during MELT. This indicates that although ice cover and air temperature are strongly correlated, a large change in ice cover brings about only a small change in air temperature. As in the mean air temperature analysis, the largest correlation coefficients and the smallest are associated with Chesterfield Inlet and Churchill, respectively. Also, the onshore air temperatures were more highly correlated with ice cover than offshore air temperatures. The regression equation intercepts indicated that onshore air temperatures were from 0.1 to 2.5 ^{o}C warmer than the temperatures for offshore winds during the NOMELT period. However, during MELT, the onshore air temperatures were from 3 to 4 ^{o}C colder than offshore ones.

The wind frequency analysis showed that for the most part, increasing onshore wind frequencies were positively correlated with increasing ice cover. Offshore wind frequencies were negatively correlated. This occurs because onshore winds push more ice shorewards. The highest correlation always occurred during MELT, for an offshore sector and did not exceed $r = -.39$, $-.58$ and $-.60$ for Chesterfield Inlet, Churchill and Moosonee, respectively. Correlations are small during NOMELT because during most of that period the ice cover is either 100% or 0% and wind from any direction will have no effect under these conditions. During MELT while the ice is dissipating, winds are able to transport the unstable ice. Ice cover was more strongly influenced by offshore winds and this could occur because other factors may be working together with the offshore wind influence. The correlation coefficients of the wind speed analysis were rarely significant.

Wind frequency, wind speed and air temperature by wind direction were examined during a maximum ice year and a minimum ice year for both NOMELT and MELT. A maximum ice year was determined as the year in which 100% ice cover existed the longest into Spring, and a minimum ice year was when break-up started the earliest. The maximum ice year was 1975, 1978 and 1973 and the minimum ice year was 1971, 1973 and 1975 for Chesterfield Inlet, Churchill and Moosonee, respectively.

When comparing the maximum ice year to the minimum ice year at Moosonee, onshore wind frequencies increased while offshore winds decreased for both the NOMELT and MELT seasons. There was no significant changes in wind frequency at Chesterfield Inlet and Churchill. At Chesterfield Inlet, wind speeds increased in the offshore and onshore sectors for both NOMELT and MELT, while at Churchill, only onshore wind speeds increased. Moosonee did not show any signficant changes in windspeed. The above observations also held true when the analysis was repeated comparing two maximum and two minimum ice years.

The air temperature analysis revealed that onshore winds were at least 0.6 °C warmer in the minimum ice year than in the maximum during MELT at all three stations. When total ice cover persists longer into the summer it keeps air temperatures colder than when it dissipates early.

4. CONCLUSIONS

The results from this study indicates the following. The length of the MELT period varies along the west coast of Hudson Bay. In general, a station's ice cover is most highly correlated with its southern neighbour. The frequency of onshore winds increases substantially from the NOMELT to the MELT period. These onshore winds which blow over the ice, are associated with air temperatures which are 3 to 4 °C colder than for offshore winds.

The linear correlation of meteorological elements with percent ice cover gives the following picture. Mean air temperature is most highly correlated with ice cover and this was more pronounced at Chesterfield Inlet than at the other two stations. Thus, freeze-up and melt at Chesterfield Inlet are stongly influenced by air temperature. In contrast, Churchill was the least influenced by mean air temperature. Therefore, the magnitude of sea ice is more strongly influenced by factors other than air temperature. These other factors are presumably wind direction and the currents of Hudson Bay.

Ice cover was more strongly influenced by air temperature during the NOMELT than the MELT periods. This shows that cold temperatures hasten freeze back more than warm temperatures hasten MELT. Again, this is most evident at Churchill where during MELT, ice cover and air temperature are least related, indicating that other factors play a major role. The offshore/onshore analysis also supports this.

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