SNOW BLOWING AND SNOW FALL ON THE NORTH SLOPE, ALASKA 650-79

By

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Introduction

This report is intended for use in engineering design and feasibility studies on the North Slope in addition to its contribution to meteorology and hydrology. Therefore, because it is addressed to a wide audience, I beg the reader's patience for statements which will lack interest for one group of readers or the other.

Blowing snow is a fairly common winter phenomenon in the polar areas. It occurs when the ground is snow covered and when relatively strong winds are blowing (normally above 15 mph or 7 m sec^{-1}). Blowing snow commonly occurs during periods of low Equivalent Chill Temperatures; at such times the chill factor and reduced visibility can make outdoor activities unpleasant if not impossible.

We studied the frequency of blowing snow and snowfall as a function of other meteorological parameters on the North Slope of Alaska. The North Slope is a relatively flat, treeless area between the Brooks Range and the Arctic Ocean; the western portion of the slope is wider than the east as the Brooks Range runs closer to the Beaufort Sea in eastern Alaska. The climate of the North Slope is not well known (Searby 1968), as studies conducted in this arctic area have been of short-term nature (Conover 1970, Kelley et al. 1964, Searby and Hunter 1971, Weller et al. 1974, Wendler et al. 1974, Holmgren et al. 1975). For more detailed references see Wilson (1967, 1969). Hence we have tried to obtain a better understanding of this area which in recent years has become very important to the economy of Alaska owing to petroleum development. This is the first of a series of investigations concerned with the climate of the North Slope of Alaska. In Canada, Burns (1973) has carried out a similar investigation for the McKenzie Valley. Furthermore, a recently published climate atlas of the Chukchi - Beaufort Sea (Brower et al., 1977) provides climatic information for the coastal areas of the North Slope.

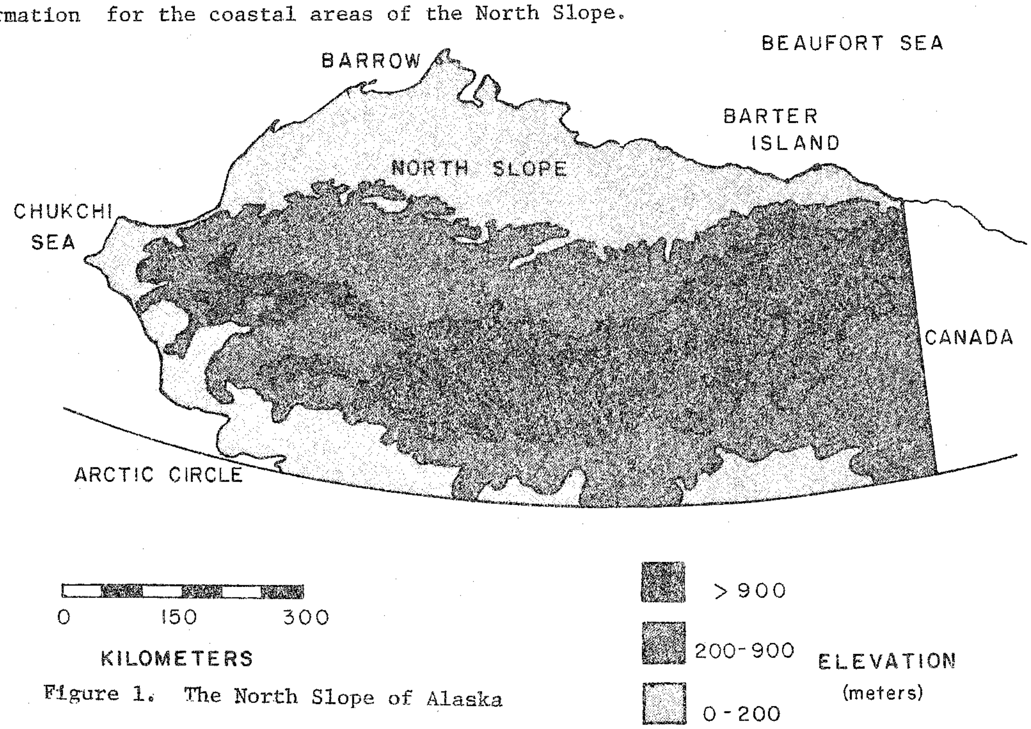

Figure 1. The North Slope of Alaska

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Data Base and Reduction

A statistical analysis of the frequency of blowing snow as a function of the time of the year, wind speed, wind direction and temperature was made for Barrow and Barter Island. Further, the frequency of falling snow, which is sometimes difficult to distinguish from blowing snow in the winter darkness of northern Alaska, was analyzed. Barrow (71°81'N, 156°47'W), the northernmost settlement of the United States, is located in the western part of the North Slope, while Barter Island (70°08'N, 143°38'W) is located on the narrow eastern portion (see Figure 1). Barrow and Barter Island are the only two long-term climatological stations in this area; this study was based on these two stations and the ten year period 1965-1974, for which 3-hourly observations were available.

On the North Slope, blowing snow normally occurs during the months of October to April; hence, we analyzed the data for this period. The total number of observations for each of the two stations was about 16,800 (3-hourly observations for 10 years). Missing data were infrequent, never exceeding 1% of the data for any chosen month.

The observations were conducted by the U.S. Weather Bureau (NOAA 1965-1974). Temperature and wind speed data were measured, while values for blowing and falling snow were based on visual observations and are therefore somewhat subjective. However, as the obervation period is long (about 15 observers were involved in gathering the data for each station over the 10 year period) errors due to subjectivity are not believed to be important. All data were obtained on magnetic tape from the Climatic Center in Asheville, N. C. The statistical analysis was made at the University of Alaska's Honeywell, Level 66 computer.

Results

The frequency of certain wind speed intervals at Barrow and Barter Island in the winter months (October-April) over the period 1965-1974 is shown in Figures 2a and 2b.

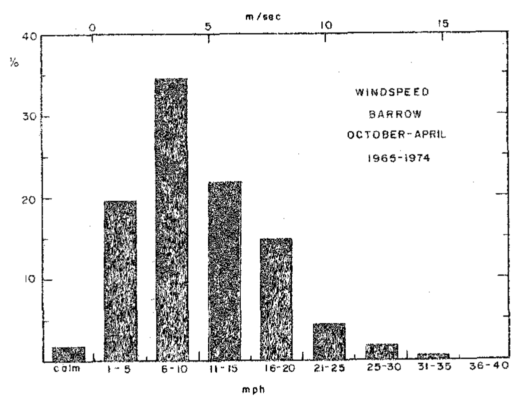


Figure 2a Barrow

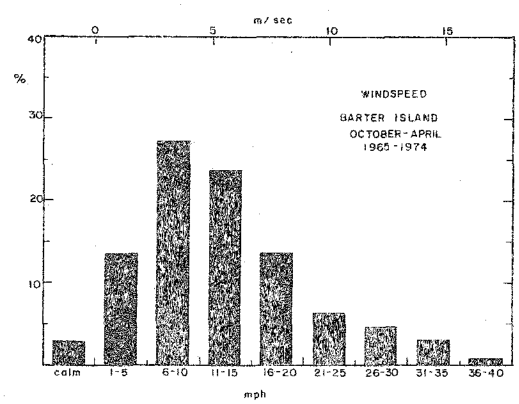


Figure 2b Barter Island

Frequency (in %) of the wind speed in certain intervals, October to April, 1965-1974.

The 6-10 mph (2.7 - 4.5 m sec^{-1})* interval is the most frequent one for both stations, followed by the 11-15 mph (4.9 - 6.7 m sec^{-1}) interval. However, the frequency of high winds (> 20 mph or > 8.9 m sec^{-1}) is greater at Barter Island than at Barrow. This result was to be expected as the long-term mean wind speed is slightly higher at Barter Island (12.9 mph or 5.8 m sec^{-1}) than at Barrow (12.0 mph or 5.4 m sec^{-1}) (Searby

*All Meteorological parameters are shown in the units in which they were measured. Metric units were added in parenthesis).

1968). Interestingly, Barrow shows a lower frequency of calms than Barter Island.

In Figures 3a and 3b the temperature is shown against wind speed for Barrow and Barter Island respectively. The analysis is again based on 10 years of data; two periods are distinguished: December, January, February and October, November, March, April. Note the increase in temperature with increasing wind speed.

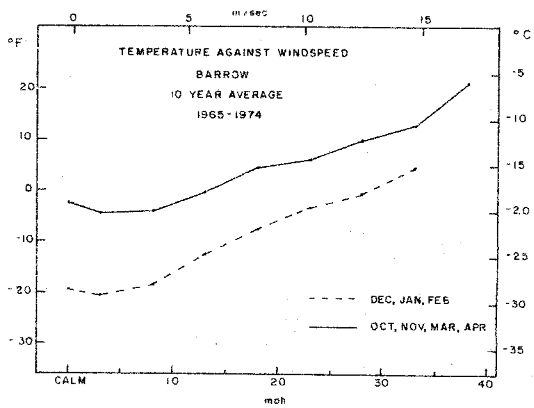


Figure 3a Barrow

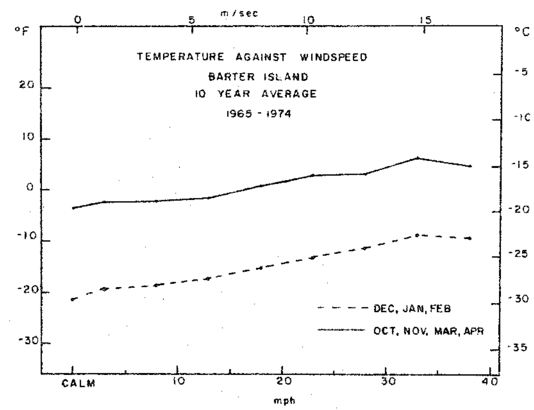


Figure 3b Barter Island

Temperature against wind speed, 10 year average (1965-1974). Values are given for midwinter (December, January, February) and for late autumn and early spring (October, November, March, April).

At Barrow (Figure 3a) the increase in temperature with increasing wind speed is nearly linear, starting from 5 mph (2.2 m sec^{-1}); a temperature increase of about 0.8°F per mph wind increase (1.0°C per m sec^{-1}) is observed for midwinter. The temperature increase with increasing wind speed is somewhat smaller for late autumn and early spring, respectively. Such a temperature increase with increasing wind speed has been observed previously, e.g. for Fairbanks by Wendler and Nicpon (1975). It is a result of the mechanical mixing caused by strong winds which destroy the surface inversion established by the negative radiation balance occurring in the Arctic in winter.

At Barter Island (Figure 3b) the temperature increase with increasing wind speed was about half that found for Barrow (0.4°F per mph or 0.5°C per m sec^{-1}). This might be due to the stronger winds observed at Barter Island which keep the atmosphere mixed and hinder the development of surface inversions. Further, the proximity of the Brooks Range to Barter Island has a considerable effect on this (Schwerdtfeger 1975).

It is a known fact that winter temperatures normally become warmer with increasing wind speeds in polar areas. Very low temperatures with very high wind speeds, e.g. a temperature below -30°F (-34.4°C) with a wind speed in excess of 25 mph (11.2 m sec^{-1}), seldom occurs on the North Slope even though temperatures below this level and wind speeds above this level are not infrequent. This condition has great practical importance, for if such temperatures and wind speeds were to occur simultaneously the equivalent chill temperature (-90°F or -68°C) would make outdoor activities of any kind very hazardous if not impossible.

The frequency of winds in excess of 15 mph (7 m sec^{-1}) is shown in Figure 4 on a monthly basis for Barrow and Barter Island.

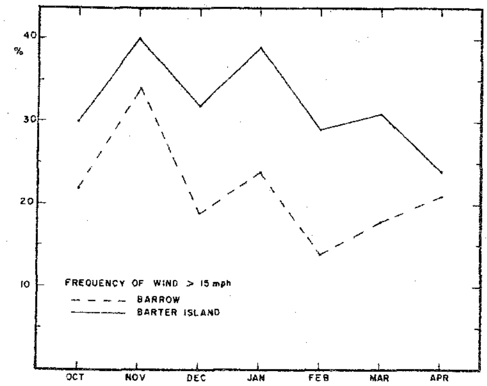


Figure 4

Frequency (in %) of wind speed in excess of 15 mph (7 m sec^{-1}) on a monthly basis for Barrow and Barter Island (10 year average 1965-1974).

15 mph (7 m sec^{-1}) is the wind speed at which the first drifting snow is normally observed. It is apparent, as expected from Figures 2a and 2b, that Barter Island has higher winds more frequently than Barrow. During November and January, the frequency of winds above 15 mph (7 m sec^{-1}) reaches nearly 40% for Barter Island, while Barrow shows lower values for all months. With the exception of April, the curves are parallel for all months.

In Figures 5a and 5b the frequency of blowing snow as function of wind speed is given for Barrow and Barter Island. As before, the data base is from 1965-1974, and the two periods of a) midwinter, and b) late autumn and early spring were again distinguished. At any specific wind speed, the frequency of blowing snow is very similar for both stations -- with the exception of very high wind speeds. However, as these highest wind speeds are infrequent at Barrow, this might be more accidental than systematic.

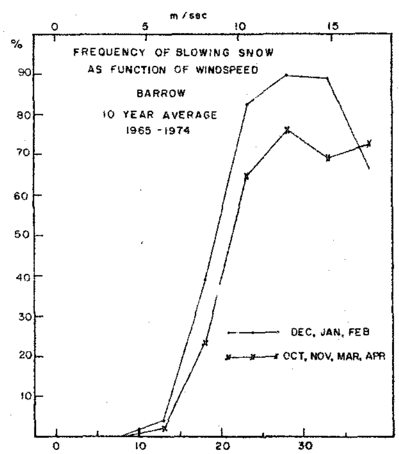


Figure 5a Barrow

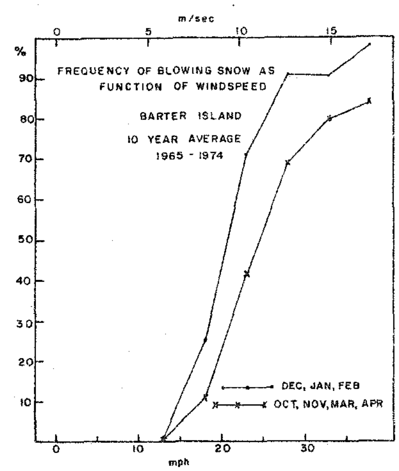


Figure 5b Barter Island

Frequency (in %) of snow blowing for certain wind speed intervals, 10 year average (1965-1974). Values are given in midwinter (December, January, February) and for late autumn and early spring (October, November, March April).

In Figures 6a and 6b the frequency of blowing snow as function of wind direction is given for Barrow and Barter Island. The data base again is from 1965-1974. For Barrow (Figure 6a), the highest occurrence of blowing snow was found with a wind direction of ENE (3.3%) and WNW (4.3%), but blowing snow was observed under all wind directions. This is not the case at Barter Island (Figure 6b), where blowing snow is most frequently observed with a westerly wind (9.36%). With easterly winds 3.5% blowing snow was observed at Barter Island, a value similar to that found at Barrow. This is understandable as the mean wind vector at Barrow is a westerly one for all winter months, however, at Barter Island it is easterly for the midwinter months (December to March (Brower et al., 1977). The higher frequency of winds parallel to the Brooks Range at Barter Island, i.e., of east and west winds, is due to the proximity of Barter Island to the mountain range.

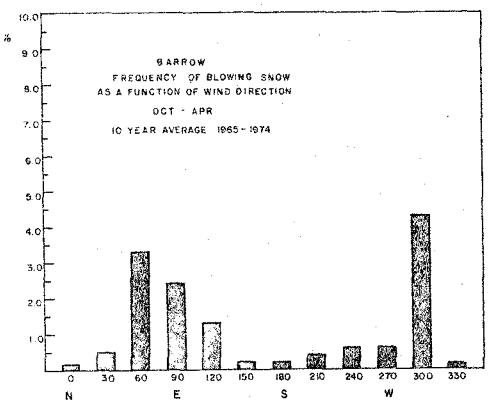


Figure 6a Barrow

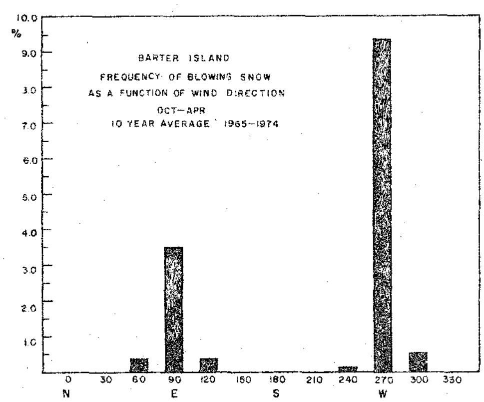


Figure 6b Barter Island

Frequency (in %) of blowing snow as a function of wind direction, 10 year average (1965-1974).

As noted above, blowing snow is sometimes difficult to distinguish from falling snow in the winter darkness in Alaska. Hence, we also analyzed the frequency of falling snow as a function of wind direction for Barrow and Barter Island (Figures 7a and 7b). At Barrow (Figure 7a), snowfall was most frequently observed with ENE winds; however, snowfall was also observed with all other wind directions. At Barter Island (Figure 7b), snowfall occurs most frequently with westerly winds, however, the distribution of falling snow for both stations is much less pronounced than that of blowing snow. It should be mentioned that precipitation gauges may catch some blowing snow, which would contribute to the observed distribution of recorded snowfall.

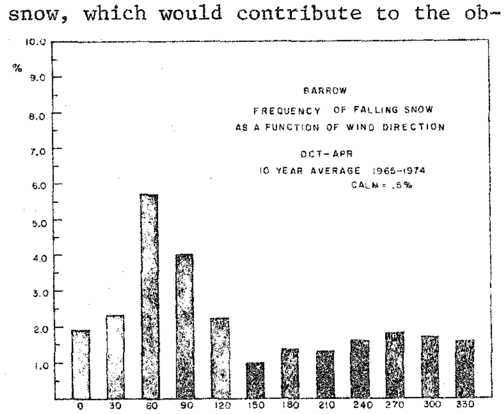
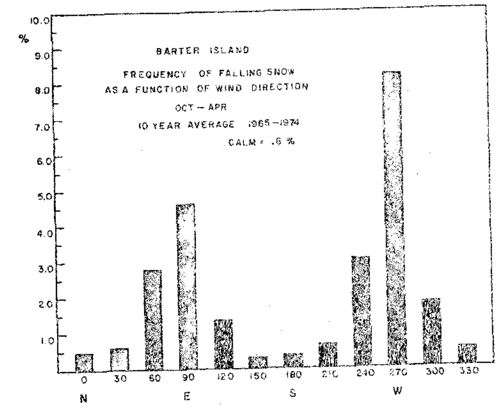


Figure 7a Barrow

Frequency (in %) of falling snow as a function of wind direction, 10 year average, 1965-1974.

Figure 7b Barter Island

Frequency (in %) of falling snow as a function of wind direction, 10 year average, 1965-1974.



It should be pointed out that all occurrences of precipitation in solid form were counted under snowfall, including snow, pellets, and ice crystals. However, as shown in Table 1, "snowfall" at both stations consisted predominantly of "light snow" and secondarily of "moderate ice crystals".

Table 1: Distribution of the kind of snowfall in percent: 1965-1974.

	Barrow	Barter Island
Snow		
Light	83.2	88.0
Moderate	0.5	0.5
Heavy	0.0	0.0
Pellets		
Light	0.0	0.0
Moderate	0.0	0.0
Heavy	0.0	0.0
Ice Crystals		
Light	0.0	0.0
Moderate	16.3	11.5
Heavy	0.0	0.0

In Figures 8a and 8b, the frequency of snow fall is given as a function of the season and wind direction. If a trend could be detected, this would give some information about the origin of the precipitation. Benson (1969) has been especially interested in this problem. However, one can see that the distribution for both stations is fairly similar to that seen in Figure 7a and 7b, which indicates that no great change in the precipitation source occurs from one winter month to another.

Figure 8a Barrow

Frequency (in %) of snowfall as a function of wind direction and season. October - April 10 year average, 1965-1974.

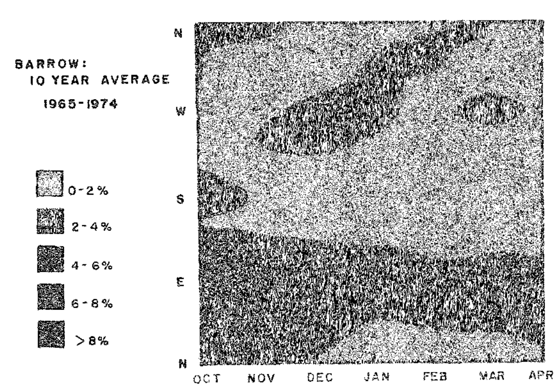
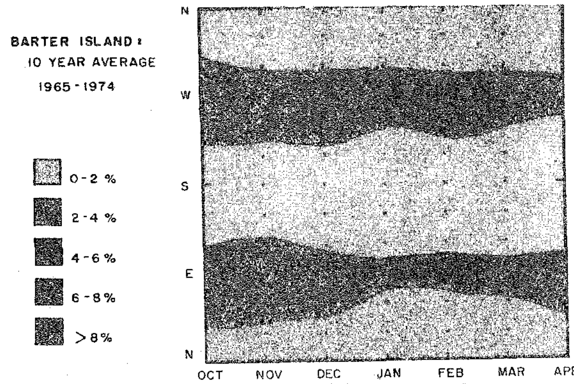


Figure 8b Barter Island

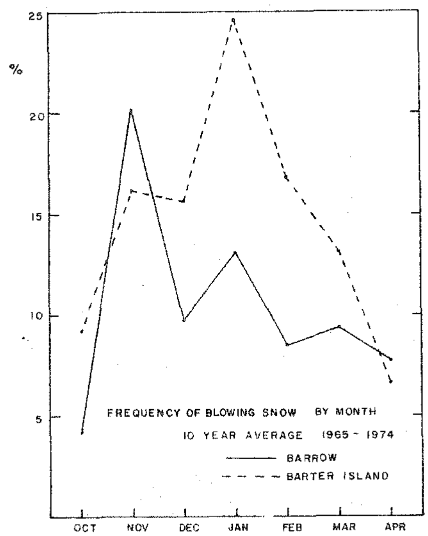
Frequency (in %) of snowfall as a function of wind direction and season. October - April 10 year average, 1965-1974.



In Figure 9 the frequency of blowing snow is given on a monthly basis for Barrow and Barter Island. Generally, Barter Island shows a higher frequency of blowing snow, a result expected from the wind data. At Barter Island the highest frequency of blowing snow was observed in January (25%), while at Barrow the maximum occurred in November when blowing snow was observed 20% of the time. The frequency of time for blowing snow for the two stations is not parallel. This indicates that wind speed is not the only factor determining the incidence of blowing snow. The availability of new snow is, of course, also of great importance.

Figure 9

Frequency (in %) of blowing snow by month, 10 year average 1965-1974, Barrow and Barter Island.



In Figures 10a and 10b the frequency of snowfall is given in percent on a monthly basis for Barrow and Barter Island. It can be seen that snowfall occurs frequently at both stations. This indicates that the snowfall is extremely light as the total precipitation is low. This supports Table 1, in that mostly "light" snowfall was recorded for both stations while "heavy" snowfall was not observed at all.

Figure 10a Barrow

Frequency of snowfall (in %) October - April, 10 year average, 1965-1974.

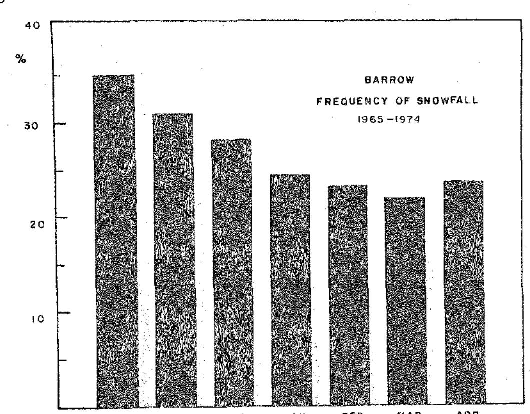
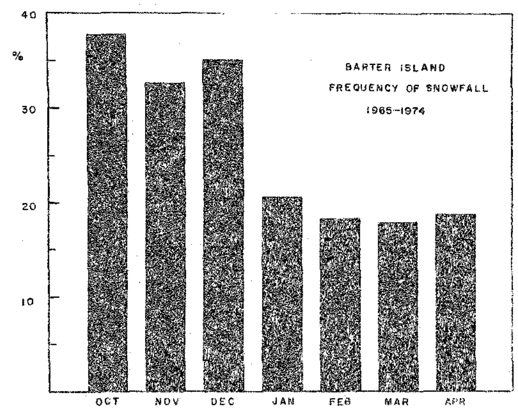


Figure 10b Barter Island

Frequency of snowfall (in %) October - April, 10 year average, 1965-1974.



The frequency of falling snow decreases fairly steadily from October to March, a not unexpected result. The Beaufort Sea is normally partially open during the fall and it functions as a water source -- one which is increasingly restricted as the ocean closes in winter. Furthermore, the ability of the atmosphere to hold water vapor decreases exponentially as it becomes colder.

In Table 2 we can see that the amount of precipitation recorded at Barter Island is substantially higher than that at Barrow. Precipitiation at both stations is recorded with standard precipitation gauges. The catch efficiency of these gauges is not very good, as noted by Black (1954) and confirmed by Benson (1976). Wind-induced errors can be large. For example, during the spring of 1976 (21 January - 23 April) the U.S. Weather Service recorded 37.3 mm water equivalent of precipitation at Barter Island. A Wyoming shielded gauge within 1/2 mile of the U.S. Weather Service site recorded 91.9 mm water equivalent, or 2.5 times the value recorded by the U. S. Weather Service (Benson 1976). Nevertheless, a relative comparison between Barrow and Barter Island is believed to be valid.

Table 2. Mean monthly precipitation at Barrow and Barter Island in water equivalent and snow.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	7 mo. total	annual total
Snowfall (Water equivalent)									
Mean 1965-1974									
Barrow									
(inches)	.49	.45	.24	.16	.10	.13	.20	1.77	4.27
(mm)	12	11	6	4	3	3	5	44	108
Barter Island									
(inches)	.54	.46	.27	.26	.15	.29	.11	2.08	5.81
(mm)	14	12	7	7	4	7	3	54	148
Snowfall									
Mean 1965-1974									
Barrow									
(inches)	6.2	5.3	3.0	1.9	1.2	1.8	2.8	22.2	34.9
(mm)	155	133	75	48	30	45	70	556	883
Barter Island									
(inches)	7.3	6.3	4.3	3.1	2.2	3.5	2.0	28.7	43.9
(mm)	183	158	108	78	55	88	50	710	1115
Snowfall (Water equivalent)									
Long term mean									
Barrow (1936-74)									
(inches)	.54	.29	.19	.20	.17	.14	.16	1.69	4.49
(mm)	14	7	5	5	4	4	4	43	114
Barter Island									
(inches)	.80	.45	.28	.60	.29	.24	.22	2.88	6.92
(mm)	20	11	7	14	7	6	6	72	176

Finally, we correlated the frequency of blowing snow with other meteorological parameters. Wind speed above certain levels as well as availability of snow are, of course, the determinant factors. We found the following empirical formula:

$$B_{cal} = a\, v_{15} + c\Delta p$$

with

B_{cal} = calculated frequency of blowing snow (%)

a = factor: for Oct = 0.2
for Nov, Apr, = 0.5
for Dec, Jan, Feb, Mar, = 0.7

v_{15} = frequency of wind speed in excess of 15 mph (%)

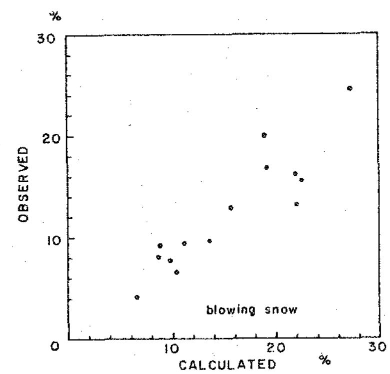
c = 0.03, constant applicable for Barrow and Barter Island

Δp = deviation in percent from monthly mean winter precipitation values for Barrow and Barter Island (can be positive or negative)

The reason why the parameter a was not assumed constant is that in fall the land surface is still uneven and the first snow (Oct/Nov) is deposited between the tussocks of the North Slope tundra. In April some melting might have occurred and formed a hard crust on top of the snow, thus preventing it from blowing. Further, the amount of snow available for re-distribution is important. Hence, we made a correction for this effect, i.e., $c\,\Delta p$. In Figure 11 we see the observed percentage of blowing snow plotted against the calculated percentage. The data points represent mean monthly values of Barrow and Barter Island; a correlation factor of 0.82 was found between measured and calculated values.

Figure 11

Calculated and observed frequencies (in %) of blowing snow on a mean monthly basis for Barrow and Barter Island.



One should be somewhat careful in using such a empirical formula, because although good values can be obtained for the long term mean, large errors might occur in any specific month. Nevertheless, this formula might prove useful for stations which record wind velocity and precipitation but do not make observations of blowing snow.

Acknowledgement

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