

SNOWFALL-WIND RELATIONSHIPS ON THE HEIBERG FOREST

by

John L. Osinski and A. R. Eschner*

Introduction

Snow seldom falls during calm periods. Wind characteristics play a major role in the snow deposition process. "How the wind blows during periods of snowfall is important in understanding the manner in which snow accumulates among trees and in open areas, and on slopes of varying inclination and orientation" (Court, 1957). From his studies in the Sierras, Court observed that only two percent of the annual snowfall occurred during calm periods.

This study is part of a project, looking at patterns of snow deposition and dissipation under various cover types on the Heiberg Forest of the S.U.N.Y. College of Environmental Science and Forestry.

Setting

The Heiberg Forest is located approximately twenty miles south of Syracuse, on the northern edge of the Appalachian Upland. The region has cold, snowy winters and cool, wet summers; precipitation generally exceeds 40 inches annually (Carter, 1966). Previous studies concluded that winter precipitation is usually associated with traveling low pressure systems and related fronts. These frontal snows, however, are sometimes augmented by "lake effect" storms with north-west winds off Lake Ontario (Muller, 1962). Winter precipitation generally occurs as snow, but sleet, freezing rain, and rain are not infrequent. Seasonal snowfall generally exceeds 100 inches.

In 1968, instruments for the evaluation of wind, temperature, and precipitation were installed on the site previously studied by Eschner and Satterlund (1963). A Bendix recording aerovane was placed on a tower at a height of 50 feet in the open field, and has provided a continuous record of wind speed and direction. In 1971, a permanent snowcourse was laid out containing 109 sample points in 6.2 acres under four major cover types, open abandoned pasture, hardwood northern forest, and red pine, and Norway spruce plantations.

Methods

Precipitation: Precipitation data from the Tully-Heiberg Forest Climatological Station (N.Y. Station 8627) was used for this study. The instruments for this station are located approximately one-quarter mile west of the snowcourses, across an open field having no barriers, and little variation between sites was expected. Precipitation was measured daily from a standard, unshielded precipitation gage, while snowfall was measured from a snowboard.

Wind: Wind speed and direction were determined from a Bendix aerovane located in the open field. A strip chart recorder provided a continuous record of both parameters.

* S.U.N.Y. College of Environmental Science and Forestry, Syracuse, New York.

In summarizing wind data, mean direction and speed were tabulated from the charts at three hour intervals. After compilation, monthly directional frequencies and average speeds by direction were calculated (Figure 1).

Storm and non-storm average speeds and directional frequencies were also determined (Figures 2 and 3). Due to the nature of the periods studied, and to provide a sufficiently large sample, a storm day was considered to be any day in which the depth of snowfall was one-half inch or more. Variation in directional frequency due to storm magnitude was also considered, by providing individual analyses for storms producing from 2.5 to 5 inches, and greater than 5 inches of snow depth (Figure 4).

Results

Precipitation: Both winters produced sub-normal snowfall for the Tully area. Although the 1972 sampling period (1 Jan.-2 May, 1972; 123 days) had 38 days with measurable snowfall, only nine days produced 2.5 to 5 inches, and only five days had snowfall (depth) greater than 5 inches. Maximum daily snowfall was 16.1 inches (2.68 inches water equivalent). Total observed snowfall during the 1972 sampling period was 104.8 inches (11.88 inches water equivalent), while total seasonal snowfall (Oct.-May), 137 inches, was slightly below the six year average of 139 inches. The February (53.2 inches) and April (11.3 inches) snowfall totals were the highest in the history of the station, however.

The 1973 sampling period (28 Nov., 1972 - 12 March, 1973; 105 days) had 34 days with measurable snowfall, but only six days produced 2.5 to 5 inches, and only two days had snowfall greater than 5 inches. Maximum daily snowfall was 7.3 inches (0.6 inches water equivalent). Total observed snowfall was 59.8 inches (4.19 inches water equivalent), while total seasonal snowfall was 84.9 inches. The monthly snowfall for January (10.2 inches), February 13.9 inches) and March (8.3 inches), and the total seasonal snowfall, were the lowest since the climatological station was established in 1967.

Wind: Wind directional frequencies, and average velocities by direction, on a monthly basis, are presented in Figure 1. An essentially bi-modal distribution can be seen in directional frequency, with peaks present in the westerly (W) and south east (SE)-south south east (SSE) directions. The W and SE components comprised from 35 to 50 percent of all observations. The plot of average speed by direction failed to produce the bi-modal distribution observed with directional frequencies. Generally, the highest average speeds were associated with the SE (10.5 mph) and SSE (9.9 mph) directions; the highest instantaneous speed, 53 mph, was from the WSW.

Analysis of variance using mean frequency by direction showed significant variation at the .05 level (Table 1). The mean frequency of SE (.1629 and W (.2189) winds were significantly different from all others. Variation in mean velocity by direction was also significant, although the range of means was much narrower.

Storm versus non-storm directional frequencies and average velocities were calculated, and are presented in Figures 2 and 3. A T-Test was performed on this data to determine if the difference in means might have represented chance occurrence, or was related to storm characteristics. The results of this analysis are presented in

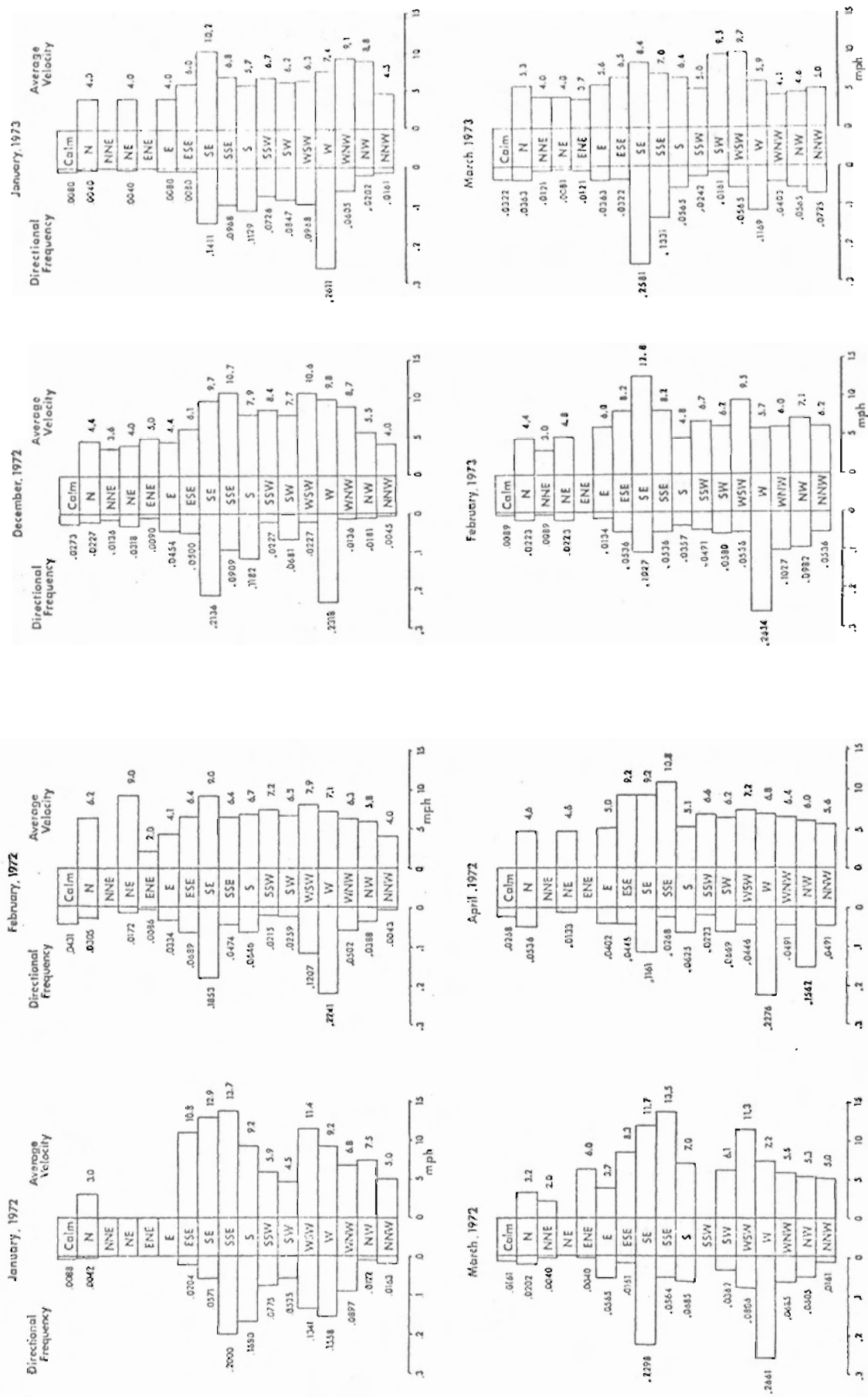


Figure 1.: Wind Directional Frequency and Mean Velocity by Direction: 1 Jan - 30 April, 1972; 1 Dec., 1972 - 31 March, 1973.

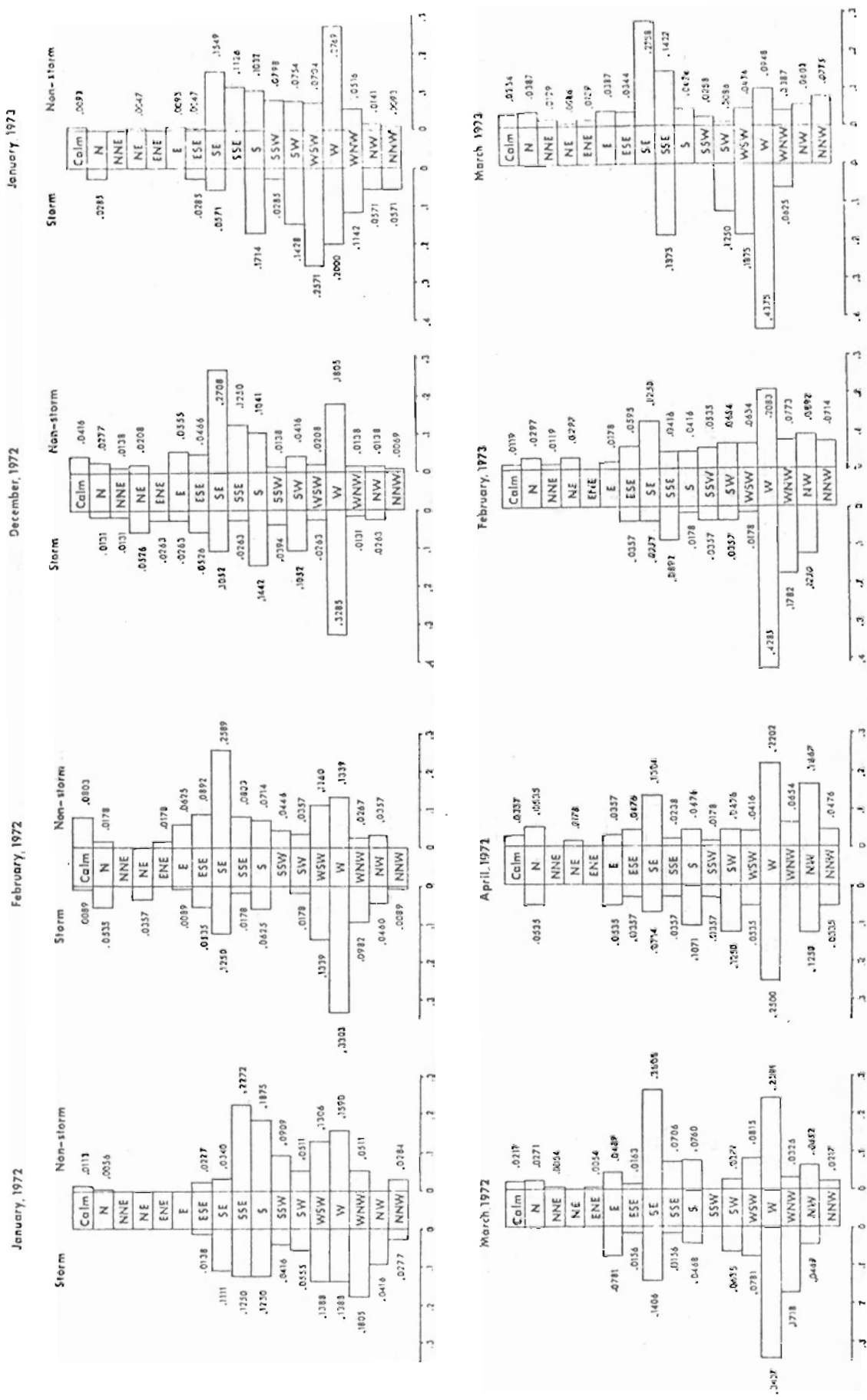


Figure 2.: Wind Directional Frequency: Storm vs. Non-storm Periods

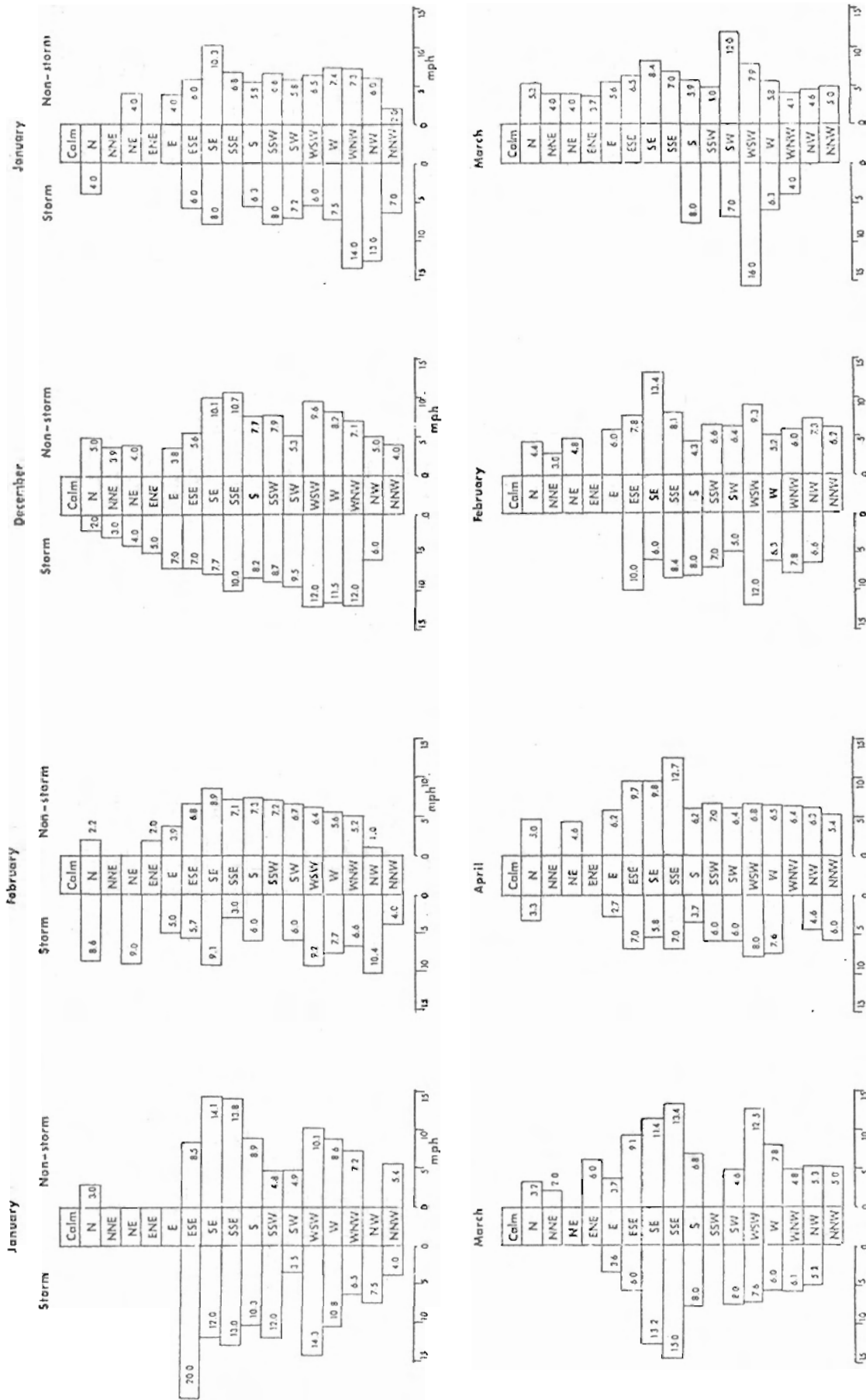
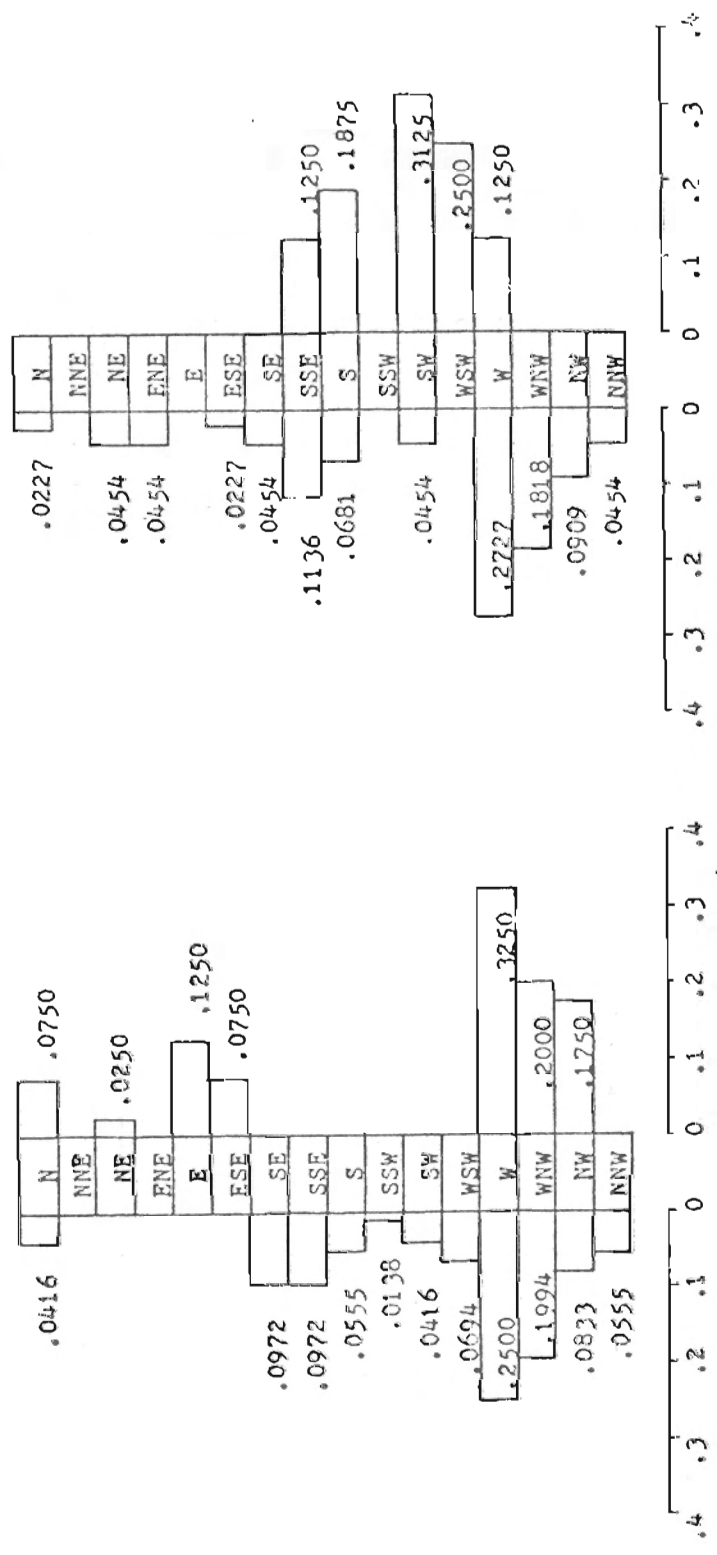


Figure 3.: Mean Wind Velocity by Direction; Storm vs. Non-storm Periods

1971-1972

Snowfall 2.5-5" (9)*
Snowfall 5" (5)*



Wind Directional Frequency

Wind Directional Frequency

Figure 4.: Storm Wind Directional Frequency as a Function of Snowfall.

Directional Frequency		Velocity by Direction	
Mean	Contrasts 1sd(.05)	Mean	Contrasts 1sd(.05)
NNE	.0048	Cal:	---
ENE	.0652	NNE	1.57
NE	.0121	ENE	2.09
Calm	.0214	NE	3.80
N	.0242	E	4.10
NNE	.0250	N	4.38
S	.0291	NNW	4.91
SEW	.0362	SSW	5.71
ESE	.0367	SW	6.16
SW	.0511	WSW	6.32
WSW	.0575	S	6.60
NNW	.0593	NNW	6.62
WSW	.0762	W	7.46
S	.0800	ESE	7.69
ESE	.0931	WSW	9.23
SE	.1629	SSE	9.96
W	.2183	SE	10.50
F calc.	20.91		15.32
P tab.	1.74		1.76

Direction	Storm vs. Non-storm Directional Frequency	Storm vs. Non-storm Average Velocity
Cal.	---	---
N	-5.3040	-0.6119
NNE	12.7700	-1.5547
NE	0.0250	-0.6150
ENE	-0.3300	-0.7331
E	-1.3593	-1.5543
ESE	-1.4003	0.1177
SE	-3.2872	2.4225
SSE	-7.2333	2.3633
S	-0.2800	1.6825
SSW	0.4052	-0.2773
SW	0.8927	1.0117
WSW	1.4145	1.5131
W	2.4225	1.9272
WSW	5.0531	0.8835
W	0.1117	1.2511
WSW	-0.9737	0.6854

: tab. (.05, 7df; 2.365)

Table 1.: Results Analysis of Variance; Wind Directional Frequency and Average Velocity

Table 2.: Results, T-Test; Storm vs. Non-storm Directional Frequency and Average Velocity.

Table 2. In the comparison of storm and non-storm directional frequencies, significant difference at the .05 level was determined for the SE, SSE, W, and WNW directions. Based on the initial data, therefore, one can conclude that the SE and SSE winds are primarily non-storm winds, while the W and WNW winds form the major snowbearing winds, accounting for up to 61 percent of all observations during storm periods.

Storm wind directional frequency as a function of storm magnitude (represented as snowfall) was analyzed in Figure 4. In 1972, the W and WNW winds had a combined frequency of .45 in all storms producing from 2.5 to 5 inches of snow, and .53 in storms greater than 5 inches. In 1973, the W and WNW directions again comprised 45 percent of all winds associated with storms in the 2.5-5 inch class, while the WSW and SW components comprised 55 percent of all winds in storms of greater than five inches.

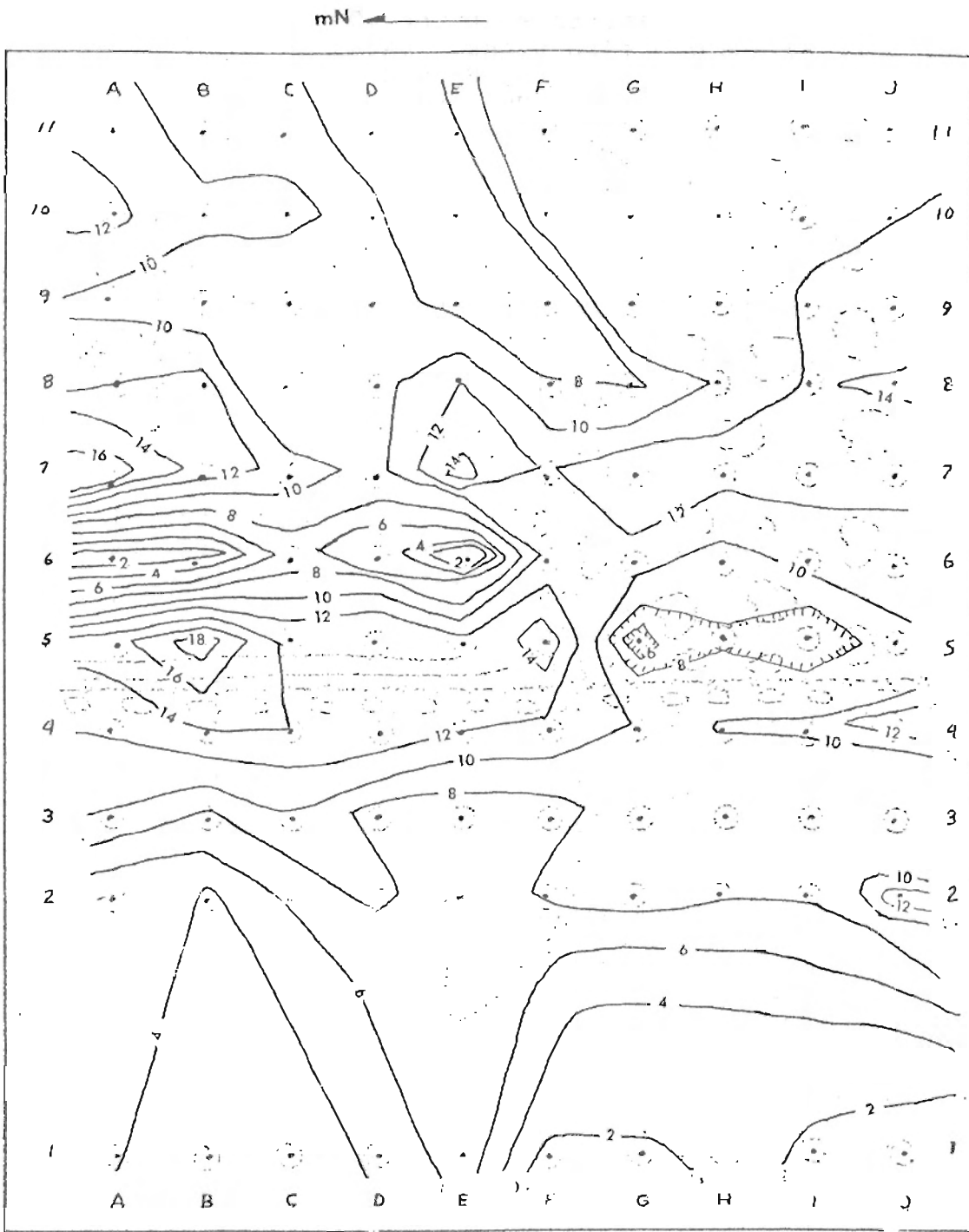
Discussion

Prior to this study, little was known of the winter wind characteristics at the Heiberg Forest. As a result of several factors, such as aspect, exposure, snowpack accumulation and drifting patterns, a strong westerly component was expected. The large SE-SSE component was therefore something of a surprise.

The SE-SSE winds were, however generally not storm winds but they still made up almost 25 percent of all observations. One possible explanation of this fact lies in the sampling method. Since the precipitation data was only collected once a day, pin-pointing the precise time that snowfall began was impossible. In examining the raw data, with few exceptions, in most major storm periods a somewhat abrupt shift in wind direction from the SE to the W was observed. The inability to isolate the beginning of the storm is largely responsible for the presence of SE winds on a storm day. The analysis of directional frequency for the larger storms, with a much smaller sample size, showed a smaller percentage of SE winds than the initial storm-nonstorm analysis. No storm day was observed during which the SE-SSE components were major elements.

The NW-WNW winds represent, to a large degree, the occurrence of "lake effect" storms. Eight storms in 1972, five of the nine in the 2.5 to 5 inch class, and three of the five in the greater than 5 inch class, based on wind data, indicate possible "lake effect" precipitation. In 1973, four of the six storms in the 2.5 to 5 inch group were "lake effect". It can be concluded, therefore, that while most storms are frontal, the major snow producing storms in the Tully area have significant augmentation due to the "lake effect".

Figure 5 is a plot of snow water equivalent on April 11, 1972, the time of peak accumulation prior to the spring melt-off. The conifer and hardwood stands, separated by a road, create a wind barrier oriented north-south. Snow borne by a westerly wind, upon interaction with this barrier, would tend to form depositional features oriented north-south, and erosional features (due to scour) oriented east-west. Such a pattern appears in the April 11 snowpack, with water equivalent contours generally oriented north-south, and a trough present in the vicinity of the road between the stands. If most deposition occurred with SE-SSE winds, a less distinct orientation of the snowpack would be expected. There is no distinct barrier to the south in the vicinity



Contour interval 2"water

Figure 5.: Distribution of Snow Water Equivalent,
11 April 1972.

of the snowcourse to upset the wind flow sufficiently to cause differential deposition or erosion. The wind field over the stand would have reestablished, and a more uniform distribution of snow within each coverytype would be expected, influenced largely by canopy density. This same orientation of the stands also reduces the possibility that the SE-SSE winds might relocate the snow after deposition.

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