MEASUREMENTS OF THE WATER EQUIVALENT OF FRESHLY FALLEN SNOW IN CANADA'S ATLANTIC PROVINCES

by

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INTRODUCTION

It is standard practice at climatological stations in Canada to measure the 24 hourly snowfall with a ruler and to estimate its water equivalent by assuming a density of 0.1. At synoptic reporting stations, on the other hand, snowfall is measured with an MSC type snowfall gauge, shielded by a Nipher shield. Snow caught in these gauges is melted and measured in order to obtain the water equivalent. The MSC snow gauge and Nipher shield are mounted on an adjustable stand so that the height of the lip of the shield can be maintained at an elevation of 60 inches above the snow surface. A complete description of the gauge and its use may be found in the instrument manuals (1).

It is well known that the density of freshly fallen snow can vary considerably. Potter (2) analysed data from stations across Canada and produced a map (Figure 1) which illustrates the variability in water equivalent of station snowfall data during January 1963. Individual measurements show even greater variability and densities have been measured in the range from .004 to 0.34. Examination of Figure 1 suggests that typical densities for freshly fallen snow in the Atlantic provinces are in the range .09 to .12. The purpose of this paper is to re-examine the problem of snowfall density using data acquired at a number of locations in the Atlantic region during 1974.

DATA COLLECTION

In this study, data from four locations were examined - Moncton, N. B., Gander, Nfld., Truro, N. S. and Halifax Airport, N. S. Meteorological staff at each of these stations routinely measure six-hourly snowfall using the MSC type gauge referred to earlier in this paper. As noted above, accumulated snowfall in the gauge during each six-hour period is melted down and the water equivalent obtained directly. For our purposes, an additional measurement program was introduced which required the observer to measure, with a ruler, the depth of snow within the gauge prior to melting same. This procedure, it was believed, yielded directly comparable snow depth and water equivalent measurements. Its main advantage over the more traditional comparison between ruler measurements made on snow boards or on the ground and water equivalent measurements obtained from gauges is one of consistency. The difficulties of obtaining a truly representative ruler measurement on the ground or on snow boards are well known. In addition, the catch characteristics of gauges are rarely known with any precision. Thus, estimates of the density of freshly fallen snow based on combinations of ruler and gauge data are fraught with uncertainty. Similarly, when the catch on snow boards is melted directly to obtain snowfall density, there remains some uncertainty as to whether the values obtained are truly representative of freshly fallen snow, due to the

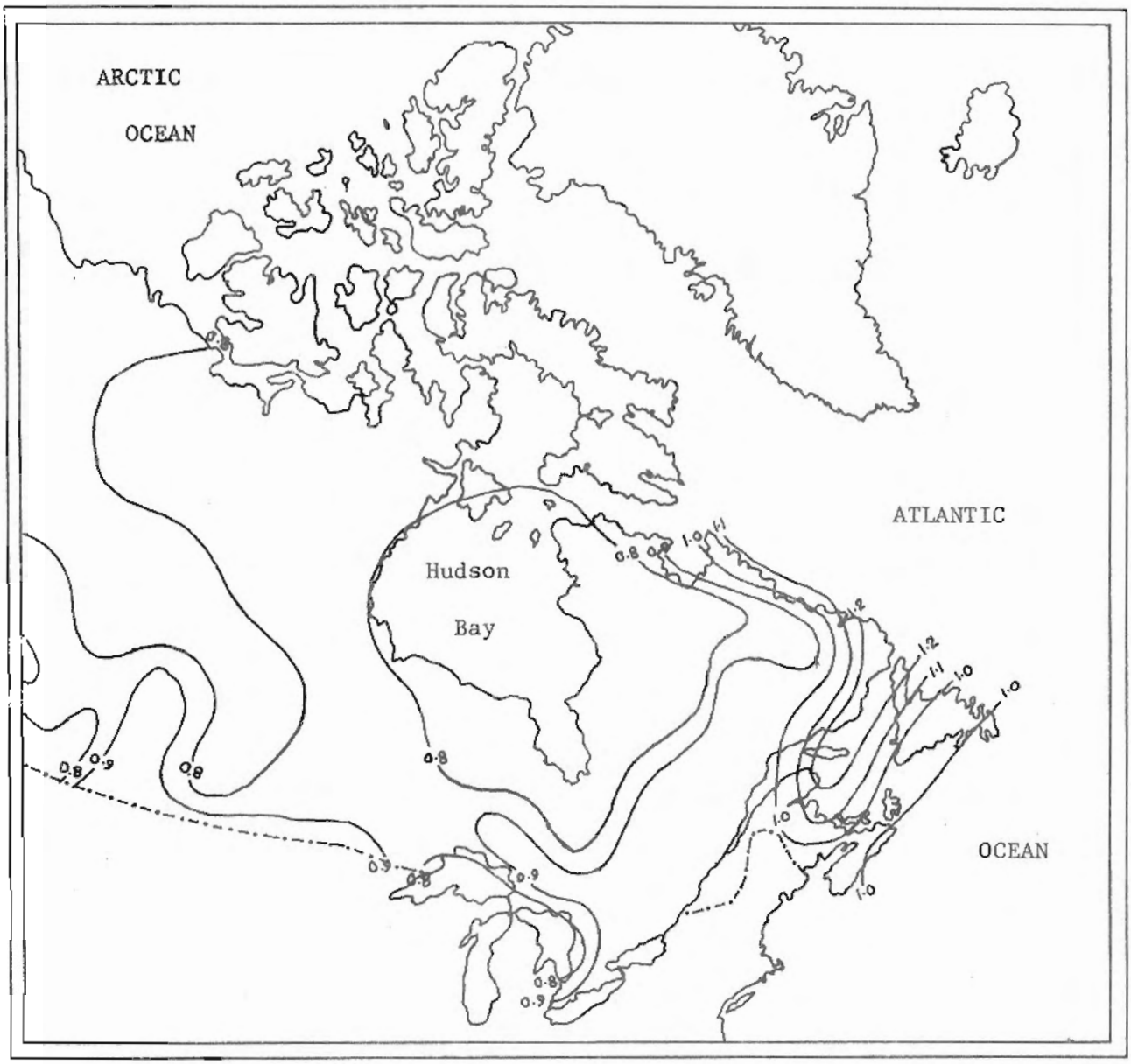

Figure 1

Ratio of the measured water content of snowfall to an estimated water content using 10 inches of snowfall as equivalent to 1 inch of water.

influences of drifting and of compaction by wind.

METHODOLOGY

Samples were selected for which the snowfall depth during a six-hour period equalled or exceeded 0.5 inches. It was felt that errors in ruler measurement of smaller amounts within the Nipher gauge would yield suspect results. For each of these samples from the four stations, we determined the snow density. For those samples taken at 0000 or 1200 GMT, the 850 mb air temperatures at sample times were determined from the appropriate 850 mb Canadian Meteorological Centre analyses. Table 1 summarizes the number of samples available from each station.

Table 1. Available snow density and 850 mb data.

Station	Gander	Moncton	Truro	Halifax A	Total
Total No. of Density Samples	40	36	21	13	110
No. of Samples Paired with 850 mb Temp.	25	20	9	6	60

The snow density at each station was plotted against the 850 mb temperature (Figures 2 to 5). Figure 6 is a plot of snow density against 850 mb temperature based on the combined data from all stations.

A snow density class width of 0.03 inches was then selected and normalized histograms drawn showing the frequency of occurrence of six-hour snowfalls by density class. The histograms for each of the four individual stations are shown in Figure 7 and the histogram for the grouped data is shown in Figure 8.

The accumulated water equivalent from all samples, taken station by station and as a group, was then determined. We also estimated corresponding accumulated water equivalents for all samples by summing the ruler measurements and assuming a value of 0.10 for the snow density. This permitted the percentage error in the estimated value to be evaluated by comparison with the measured total water equivalent. Table 2 illustrates the results of this comparison. As will be noted, the error in water equivalent arising from the assumption of a snow density of 0.1 ranged from -15% at Moncton to + 22% at Truro. When data from all stations were combined, the percentage error was 6%.

Table 2. Measured water equivalent of freshly fallen snow at locations in the Atlantic provinces compared to the estimated water equivalent obtained when a snow density of 0.1 is assumed.

Station	Moncton	Gander	Truro	Halifax A.	Total
Measured	7.36	7.64	4.13	3.41	22.54
Estimated	6.22	9.20	5.03	3.50	23.95
Percent Error	-15	20	22	3	6

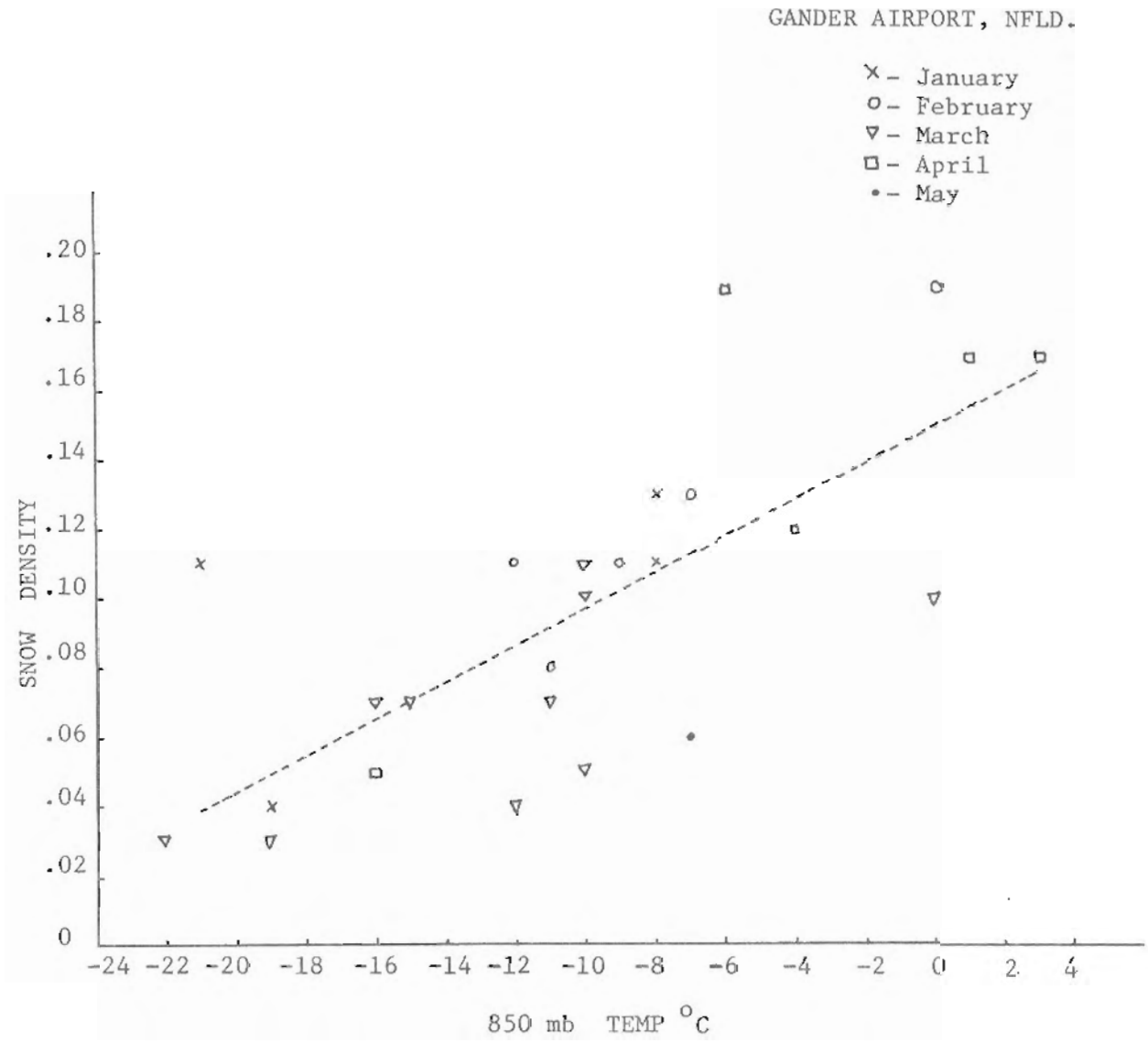

Figure 2

Snow density versus 850 mb temperature at Gander, Nfld.

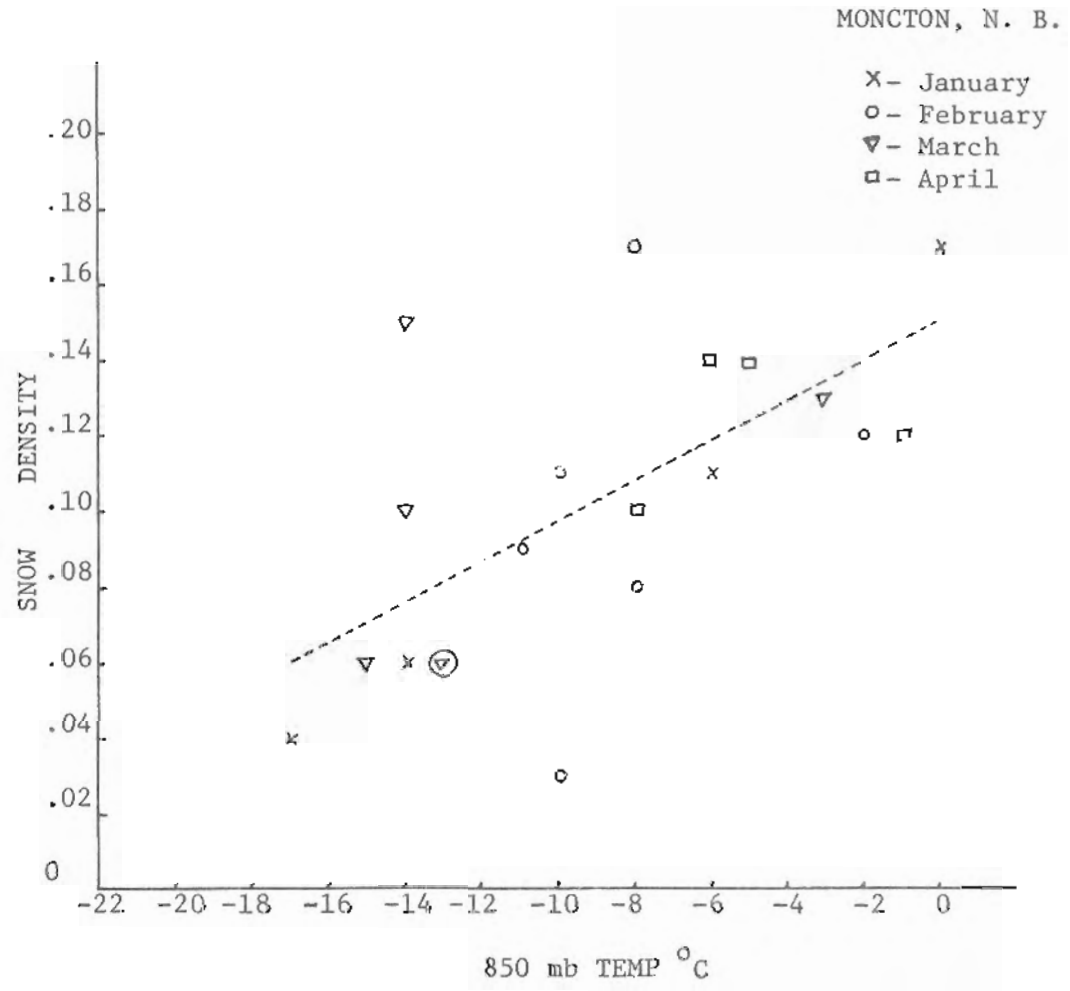

Figure 3

Snow density versus 850 mb temperature at Moncton, N. B.

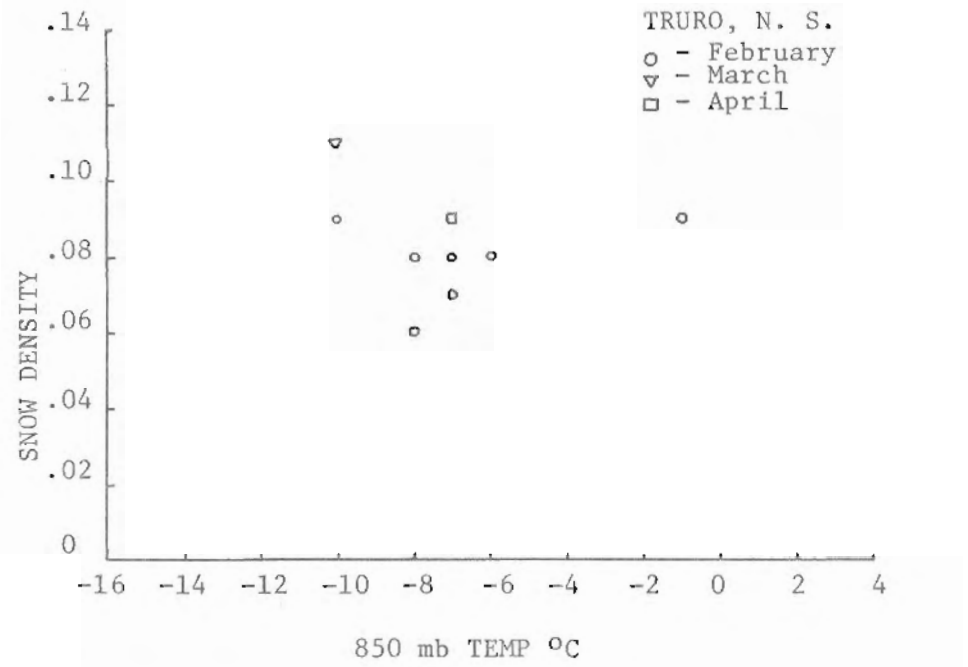

Figure 4.

Snow density versus 850 mb temperature at Truro, N.S.

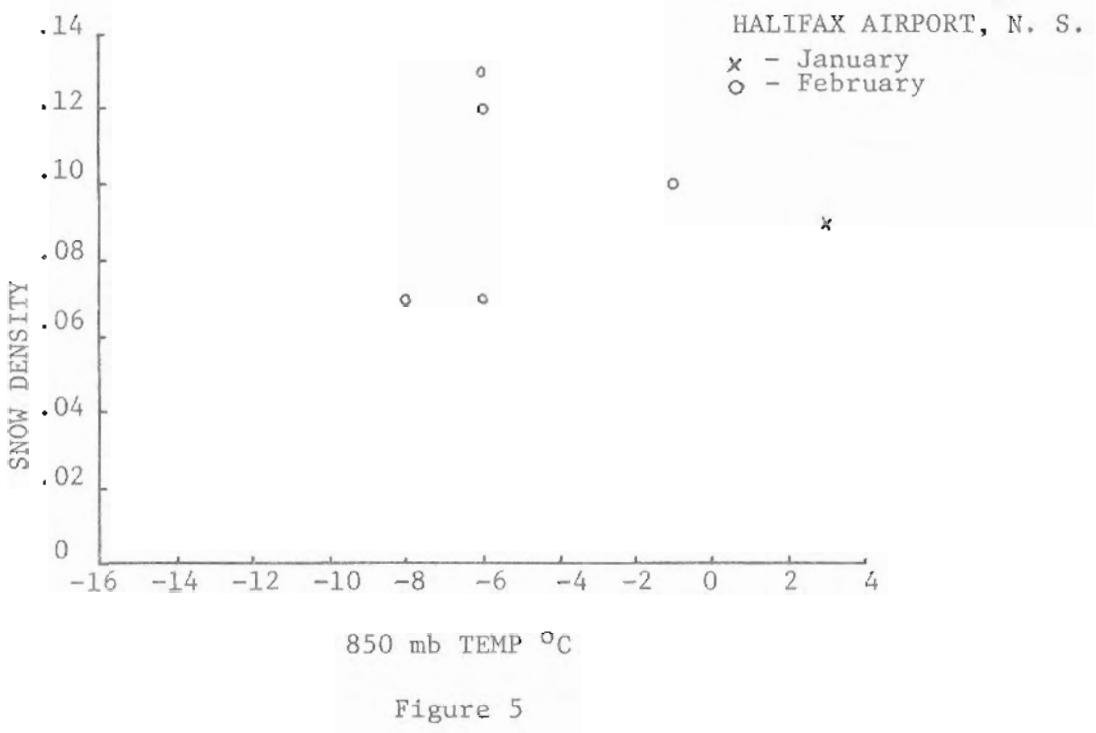

Figure 5

Snow density versus 850 mb temperature at Halifax Airport, N.S.

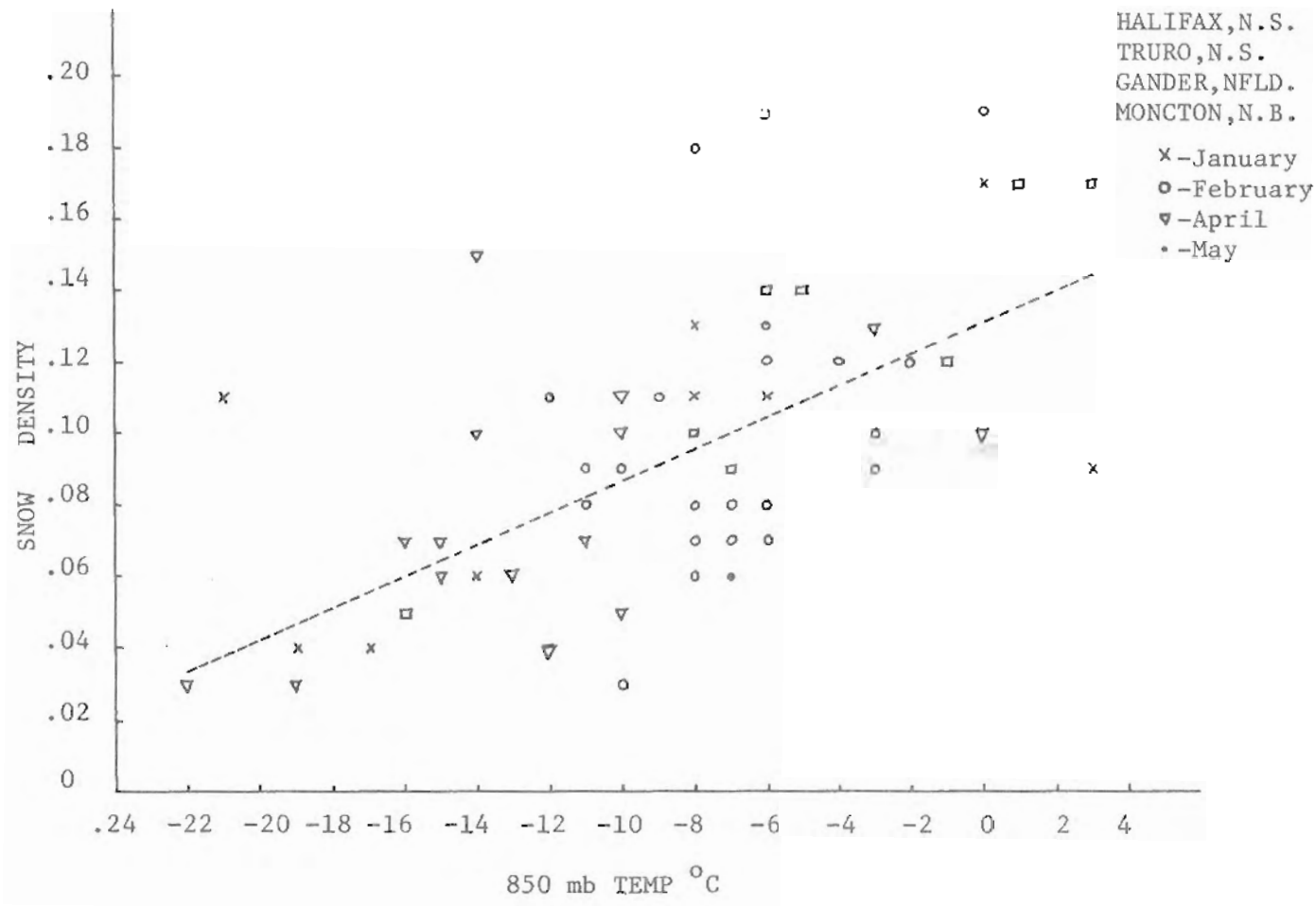

Figure 6

Snow density versus 850 mb temperatures in the Atlantic provinces.

RESULTS

Figures 2, 3 and 6 suggest that there is a linear relationship between snow density and 850 mb temperature. This relationship is, however, rather weak as indicated by the scatter in the graphs and by the fact that for our largest and best samples, Gander and Moncton, only 55 and 41 percent of the variance is explained. The linear correlation coefficients between the snow density and the 850 mb temperatures were 0.74, 0.65, and 0.60, for Gander, Moncton, and for the grouped data, respectively. Samples from Truro and from Halifax were not large enough to determine a meaningful least squares line.

The frequency distributions in Figures 7 and 8 exhibit distinct peaks in the class interval 0.09 to 0.11, with the exception of that for Truro. Closer exmination of the Truro data revealed that of the 21 samples available, there were 7 which had a density of 0.08, sufficient to shift the peak to the lower class interval. In total, 110 samples were examined. The snowfall densities measured ranged from 0.03 to 0.19, and the mean density for all the samples was 0.094.

DISCUSSION

The major conclusion of this study is graphically summarized in Figures 7 and 8. These frequency distributions confirm that the average snow density value of 0.10, used by the Canadian Atmospheric Environment Service, is indeed a reasonable assumption for the four Atlantic stations examined. The results also suggest a linear relationship between snow density and the 850 mb temperature at the time of snowfall. It may be possible, in special circumstances, to use such a relationship to obtain a better estimate of the water equivalent of a particular snow pack.

In Figure 9, our results are compared with those of Diamond and Lowry (3), and with some unpublished results of B. Goodison (4). Diamond and Lowry correlated snow densities against 700 mb temperatures for a site in the Sierra Nevada at an elevation of 6900 feet. Thus the temperatures used were from an altitude roughly 3000 feet above ground. Their correlation coefficient was 0.64 and our results agree very well with this. Goodison's data were collected at Bolton, Ontario, 20 miles northwest of Toronto. He obtained a correlation coefficient of 0.42 between snow density and 850 mb temperature. The slopes of all three lines in Figure 9 are very similar, which implies a relatively consistent relationship between fresh snowfall density and temperatures aloft in three widely separate areas.

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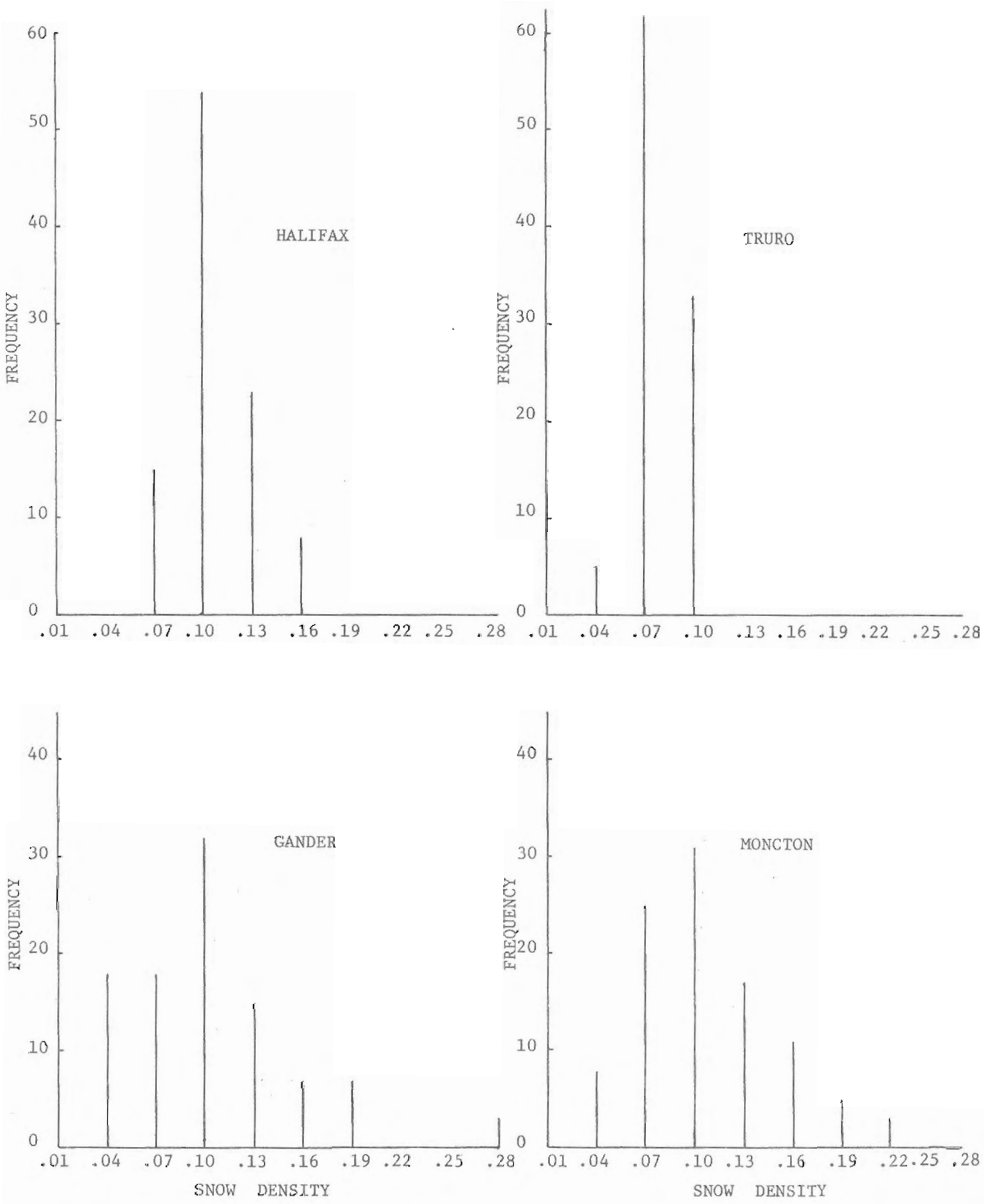

Figure 7 Frequency distributions of snowfall densities at four locations in the Atlantic provinces.

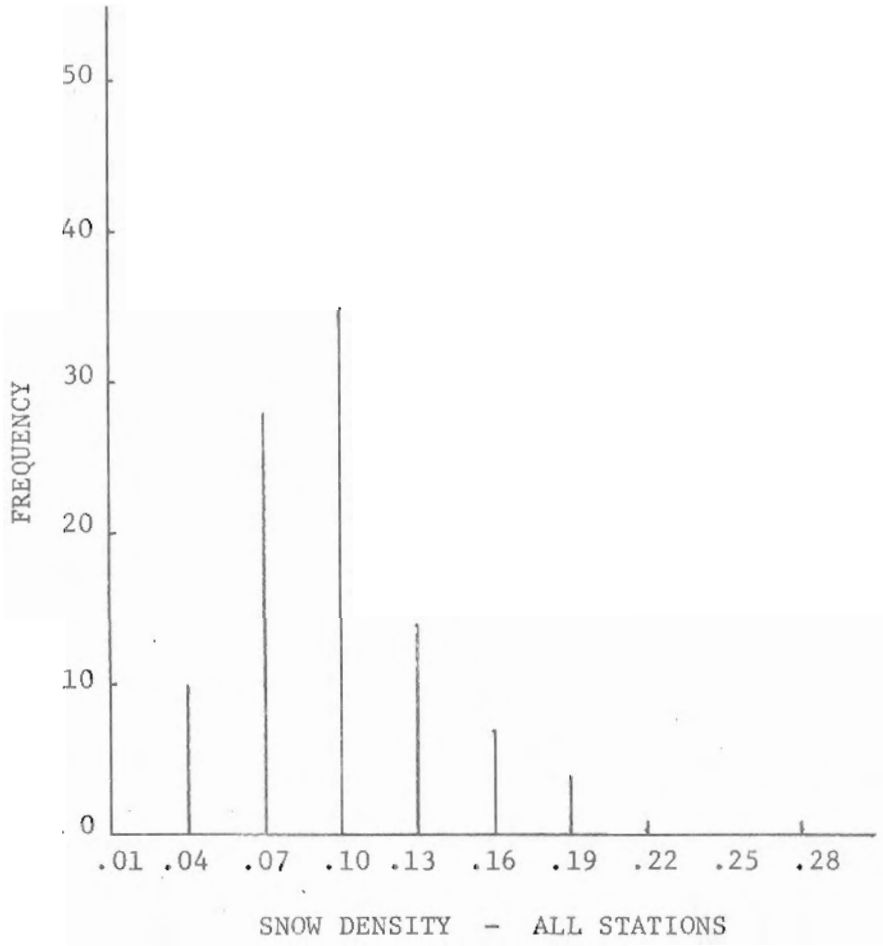

Figure 8

Composite frequency distribution of snowfall densities in the Atlantic provinces.

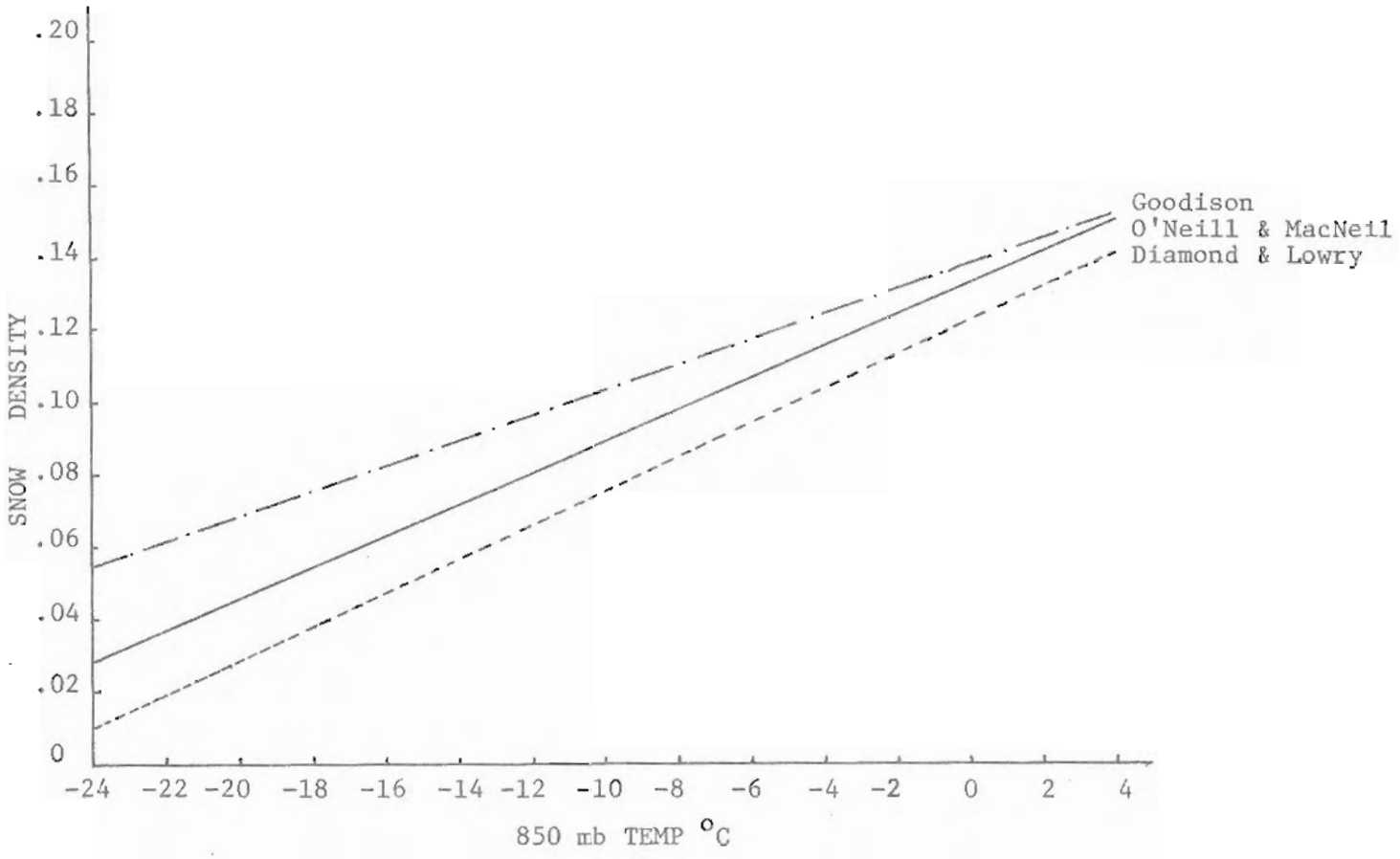

Figure 9

Snow density versus 850 mb* temperatures from three independent sources. (*Note that Diamond and Lowry's temperature data refer to an altitude of about 3000 feet above ground and not strictly to the 850 mb level.)

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4. Goodison, B., 1976: "Correlation of Density of New Fallen Snow with 800 mb and 700 mb Temperatures". (Unpublished Note)