

AN INVESTIGATION OF WOODLAND SNOW THERMAL REGIME IN THE
SCHEFFERVILLE AREA, NORTHERN QUEBEC

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ABSTRACT

Detailed measurements of temperatures within a winter snow cover and a melting spring snow cover are briefly discussed. A sampling technique was devised to obtain a great number of temperature measurements within 10 x 10 metre study plots. A spatial correlation between forest canopy and snow-ground interface temperatures was noted. It is mainly a function of snow depth variations induced by the canopy.

INTRODUCTION

The thermal regime within a snow cover is highly variable in a woodland situation. However, little attention has been given to this fact in the literature. Some snowpack temperatures have been reported by Bergen (1963, 1968, 1978), Quick (1967), Bilello et al. (1970), Trabant and Benson (1972) and Bates and O'Brien (1985), but in general, the literature on this topic is sparse.

This paper presents preliminary measurements of temperature variations in a cold snowpack during the month of February 1985 and a near-melting snowpack during the month of April 1985. The project is serving as a pilot study to an intensive monitoring of spatial and temporal variations of snow, ground and snow-ground interface temperatures.

STUDY AREA AND FIELD MEASUREMENTS

Field measurements were undertaken at several sites in an open woodland on the McGill Subarctic Research Station snow course near the town of Schefferville (54° 48'N, 66° 49'W), Northern Quebec. The dominant tree species in this forest are black spruce (*Picea mariana*) and larch (*Larix laricina*) ranging between 1 m and 12 m in height and a crown cover density ranging between 8 and 20 per cent. The underbrush consists of dwarf-birch (*Betula glandulosa*) of less than one metre in height and the ground surface includes a 4 to 9 cm lichen mat (*Cladonia* spp.) with patches of sphagnum.

Spatial surveys of snow temperatures and analyses of the density stratification of the snowpack were made on rectangular grids of 10 x 9 m and

10 x 11 m. Standard methods were used to determine snow stratigraphy, snow depth and water equivalent. Snow densities were obtained at intervals of 5 cm using a Swedish snow sampler (volume 1 litre) (Granberg, 1984a) and grain sizes for each density sample were determined through the sieve analysis method (Keeler, 1969; Granberg, 1984b).

A mobile probe system was used for detailed spatial surveys (Figure 1). Each probe consists of a single temperature sensor (Fenwall GB32P2) at its tip and enables accurate snow temperature profile measurements (better than ± 0.1 °C) to be made in a short time span (Granberg, 1984c). Resistance readings were made with a digital multimeter. The system has ten probes that are vertically inserted and lowered in steps of 5 cm into the snowpack. Air temperatures were also recorded 1 metre above the snow surface intermittently throughout each survey.



Figure 1. Set-up of snow temperature probes along a survey grid.

RESULTS

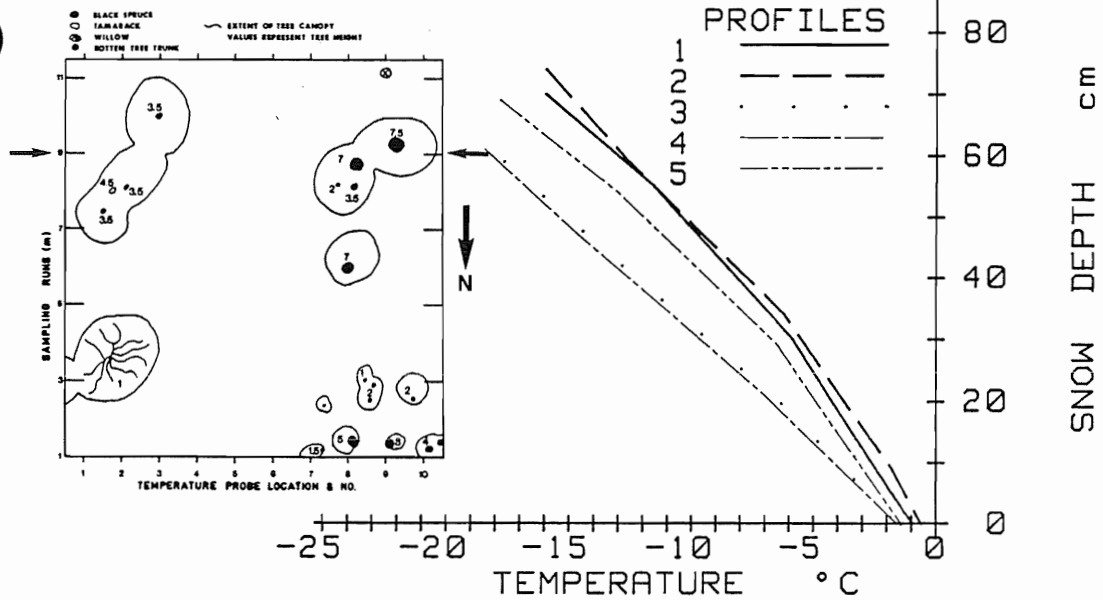
I. Snow and Snow-Ground Interface Temperatures

Observations at the study sites revealed a wide spatial variability in temperatures within the snowcover. The variations appear to be related to snow depth, snow cover stratification, forest canopy distribution and air temperature. The snow temperature profiles for the ninth sampling run of a February site (SC-1) in Figures 2a and b demonstrate the thermal variations of a snowpack in response to forest canopy densities and snow depth. A relatively cold interface temperature regime exists near trees where the snow cover is shallow and trees shade the surface. A different temperature regime exists in openings between the trees (Figure 2a, Profiles 1 to 5) where a deep snow cover leads to warm temperatures at the snow-ground interface. Much of the data in February indicate a gradual steepening of the temperature gradient towards the snow surface. Figure 3a is a map of snow-ground interface temperatures at the grid shown in Figure 2a. Figure 3b shows the depth of snow at the site. The figures illustrate a strong relationship between snow depth and ground temperatures.

SNOW TEMPERATURES AT SC-1-9A

DATE: 21.02.85

(a)

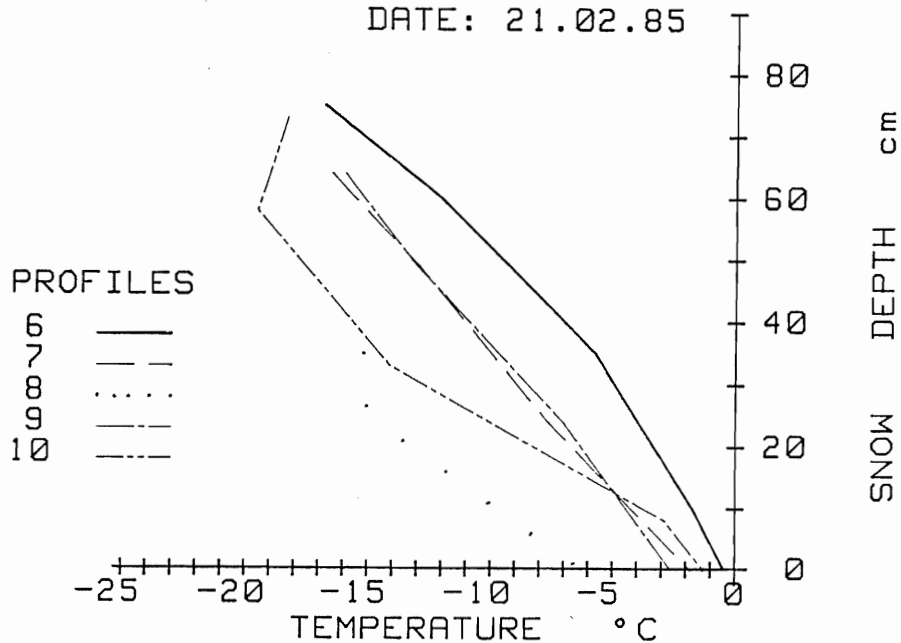


TIME: 15:10 TO 15:40
AIR TEMP.: -16.2 TO -17.0 °C

SNOW TEMPERATURES AT SC-1-9B

DATE: 21.02.85

(b)



TIME: 15:10 TO 15:40
AIR TEMP.: -16.2 TO -17.0 °C

Figure 2. Snow temperature profiles for the ninth sampling run of a 10 x 11 m grid (SC-1) in February 1985. (a) Profiles 1 to 5 were obtained in a deep snow cover. (b) Profiles 6 to 10 were obtained in a deep to shallow snow cover.

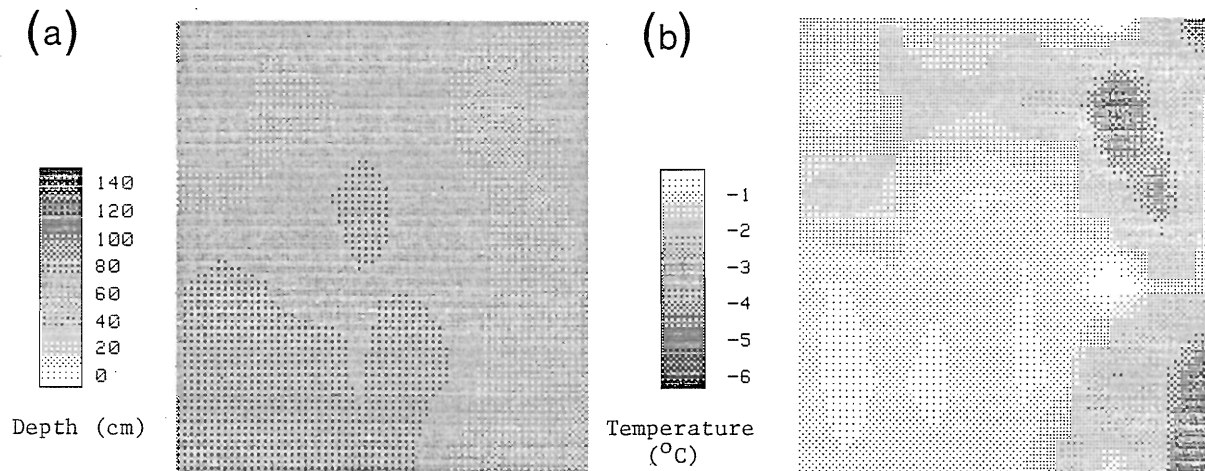


Figure 3. Spatial distribution of (a) snow depth and (b) snow-ground interface temperatures at SC-1 on February 21, 1985. Very cold interface temperatures are located in areas overlain by shallow snow cover and interface temperatures near to the freezing point are located in areas where snow cover is deep.

The April data (SC-3) (Figures 4a and b) indicate a considerable change in thermal regime as compared to the February data. In general, there is a pronounced increase in temperature near the snow surface due to surface melt followed by a gradual decrease down to the snow-ground interface. The temperature profiles for the ninth sampling run of SC-3, demonstrate interesting surface temperature variations of a snowpack in April. Warm snow surface temperatures occurred near trees while in open areas, the surface temperatures were well below freezing. Nocturnal minimums are also present in certain profiles with similar gradients at depth.

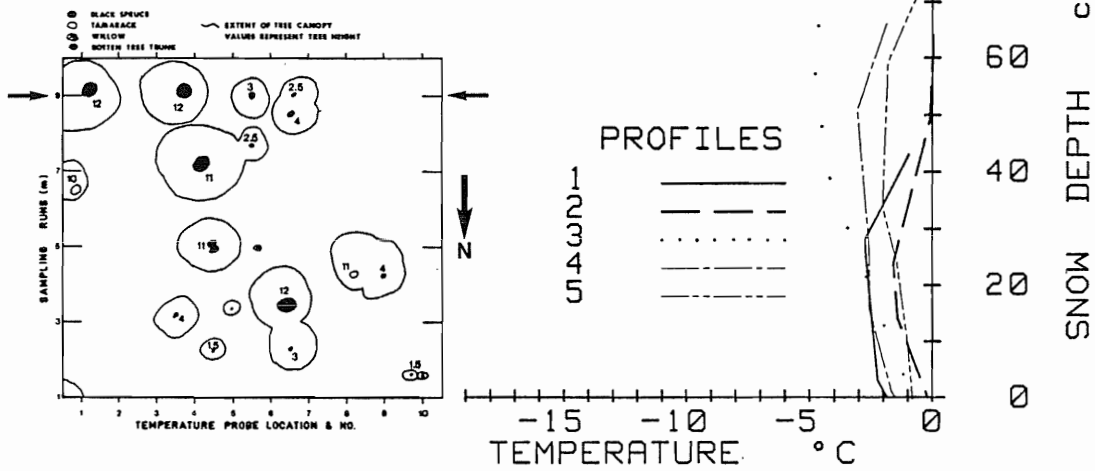
Temperatures at the snow-ground interface were first investigated in December 1984. The shallow snowpack at that time of year consisted mainly of loose snow with a poorly developed depth hoar layer of 6 cm. Interface temperatures fluctuated through a wider range for the sites observed in December 1984 and February 1985 than in April 1985. The average temperature at the interface was 1.3°C lower in December 1984 than February 1985 (-2.8°C versus -1.5°C), and 0.6°C lower in February than in April (-1.5°C versus -0.9°C). Interface temperatures ranged from -12.7°C to $+1.0^{\circ}\text{C}$ in December 1984, -9.9°C to -0.1°C in February 1985 and -3.0°C to 0.0°C in April 1985.

II. Densities

Analyses of snow stratigraphy show mean stratum densities ranging from 145 to 275 kilograms per metre cube at SC-1 (February) and from 230 to 310 kilograms per metre cube at SC-3 (April). The density of each 5 cm layer for SC-1 and SC-3 are shown in Figures 5 and 6, respectively. Both sites show similar grain size variations. A decrease in the fractions let through by the 0.25 mm to 2.00 mm sieves is noted. Twenty centimetres of depth hoar was observed in February and 45 cm in April with large cup-shaped crystals, some of which ranged from 2 to 4 mm in size. The presence of an ice layer at both SC-1 and SC-3 may have impeded the vapor migration from the snow-ground interface layer upwards through the snowpack and may have affected the densities.

(a)

SNOW TEMPERATURES
AT SC-3-9A
DATE: 23.04.85

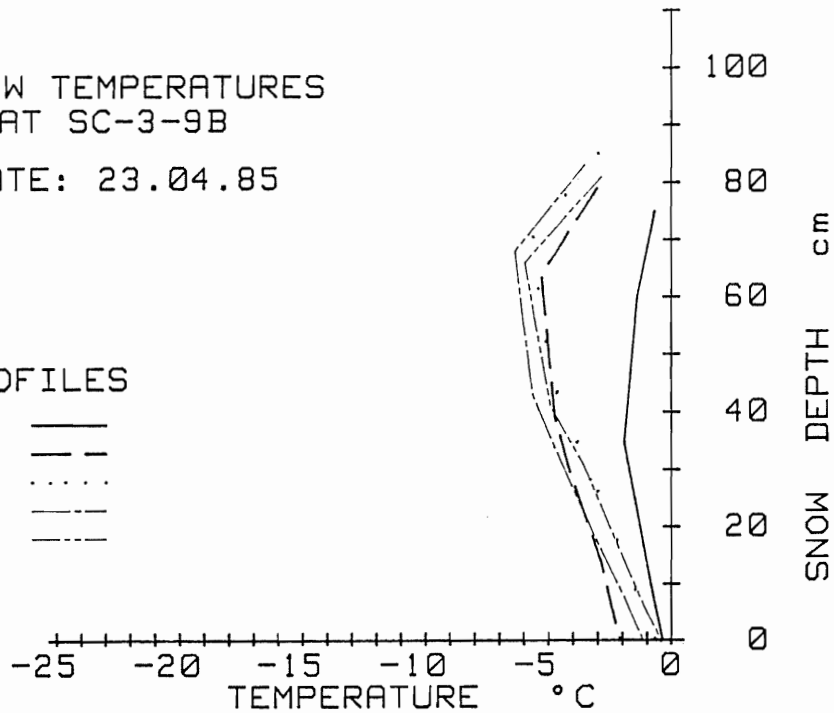


TIME: 17:20 TO 18:00
AIR TEMP.: 2.9 TO 1.0 °C

(b)

SNOW TEMPERATURES
AT SC-3-9B
DATE: 23.04.85

PROFILES
6 ———
7 ———
8 ·····
9 ———
10 ———



TIME: 17:20 TO 18:00
AIR TEMP.: 2.9 TO 1.0 °C

Figure 4. Snow temperature profiles for the ninth sampling run of a 10 x 9 m grid (SC-3) in April 1985. (a) Profiles 1 to 5 were obtained in a deep snow cover and in proximity to tree trunks. (b) Profiles 6 to 10 were obtained in a deep snow cover in an open area.

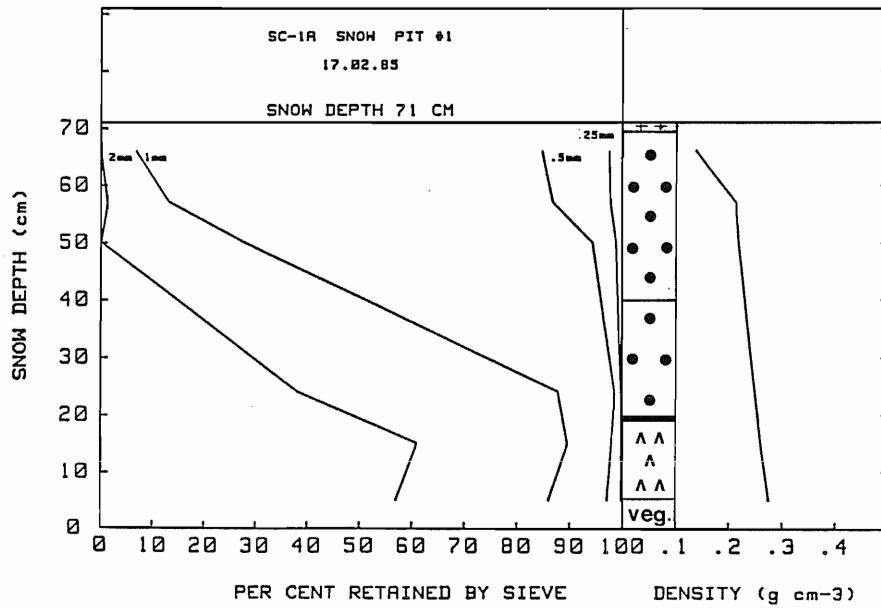


Figure 5. Snow stratigraphy at SC-1 in February 1985. Grain size analysis, description and density of the snowpack is illustrated.

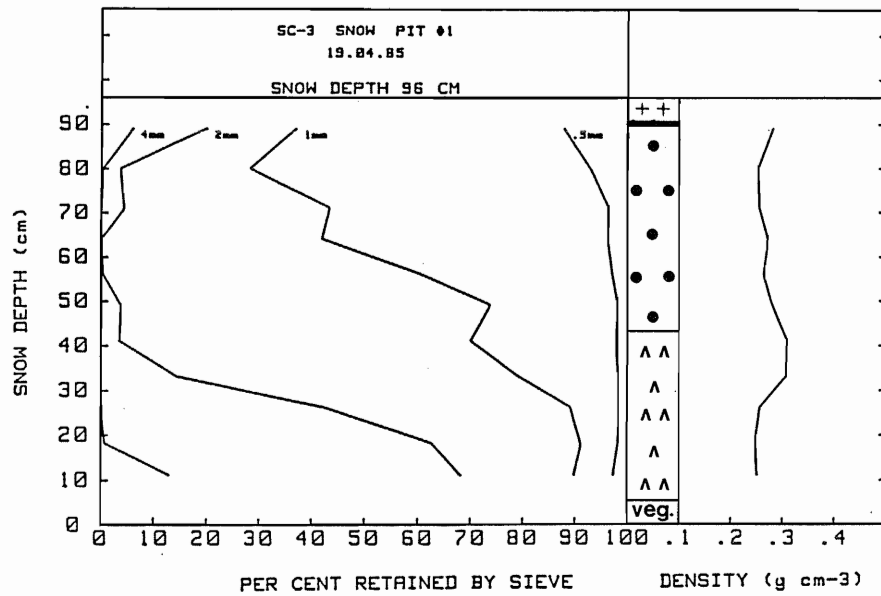


Figure 6. Snow stratigraphy at SC-3 in April 1985. Grain size analysis, description and density of the snowpack is illustrated. Note the thick depth hoar layer versus that of Figure 5.

CONCLUSION

Our limited analysis has shown that snow-ground interface temperatures are colder in a shallow snow cover and warmer in a deep snow cover. These variations also relate to forest canopy distribution through its influence on snow depth. Snow surface temperature may also vary strongly in relation to canopy distribution.

The destructive sampling technique used for this type of investigation unfortunately prevents any ongoing measurements at the same plot over the winter field season. However, it serves as a good indicator of temperature fluctuations and variations, both spatially and temporally, for a particular study area. Our surveys indicate a general reduction of the spatial variability in snow-ground interface temperatures through the winter. Minimum interface temperatures of -12.7°C in December 1984, -9.9°C in February 1985 and -3.0°C in April 1985 were observed at the study plots.

This investigation has given us preliminary values for a more intensive monitoring of snow-ground interface temperatures that will take place in the 1986-87 season (Desrochers and Granberg, this volume).

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REFERENCES

- Bates, R.E., and O'Brien, H.W. 1985. Meteorological and snow cover measurements at Grayling, Michigan. Proceedings of the 42nd Annual Eastern Snow Conference, Montreal, pp. 212-229
- Bergen, J.D. 1963. Vapor transport as estimated from heat flow in a rocky mountain snowpack. International Association of Science Hydrology, 61, pp. 62-74.
- Bergen, J.D. 1968. Some observations on temperature profiles of a mountain snow cover. U.S. Dept. of Agriculture, Forest Service, Research Note RM-110.
- Bergen, J.D. 1978. Some measurements of settlement in a rocky mountains snow cover. Journal of Glaciology, vol. 20, no. 82, pp. 141-148.
- Bilello, M.A., Bates, R.E., and Riley, J. 1970. Physical characteristics of the snow cover, Ft. Greely, Alaska, 1966-67. U.S. Army Cold Regions Research and Engineering Laboratory, Technical Report 230, 32p.
- Desrochers, D.T., and Granberg, H.B. This volume. Preliminary results of a study on snow and ground thermal regimes in the Schefferville area, Northern Quebec. 43rd Annual Eastern Snow Conference, Hanover, NH.
- Granberg, H.B. 1984a. A report on the Swedish snow density sampler. DSS Contract no. 8 SU81-00094, Instrument Report no. 2, Defence Research Establishment Suffield, Sp.

Granberg, H.B. 1984b. Sieve analysis of snow. DSS Contract no.8 SU81-00094, Instrument Report no. 5, Defence Research Establishment Suffield, 21p.

Granberg, H.B. 1984c. Design and manufacture of a thermistor probe of low heat capacity for snow thermometry. DSS Contract no. 8 SU81-00094, Instrument Report no. 1, Defence Research Establishment Suffield, 7p.

Keeler, C.M. 1969. Some physical properties of alpine snow. U.S. Cold Regions Research and Engineering Laboratory, Technical Report 271.

Quick, M.C., 1967. A comparison of measured and theoretical snowpack temperatures. Journal of Hydrology, 5, pp. 1-20.

Trabant, D., and Benson, C. 1972. Field experiments on the development of depth hoar. In: Studies in Mineralogy and Precambrian Geology. Geological Society of America Memoir 135, pp. 309-322.

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