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Experiment Station

SOME RELATIONSHIPS AMONG AIR, SNOW, AND SOIL TEMPERATURES AND SOIL FROST

Each winter gives examples of the insulating properties of snow cover. Seeds and soil fauna are protected from the cold by snow. Underground water pipes are less likely to freeze under snow cover. And, according to many observers, the occurrence, penetration, and thaw of soil frost are affected by snow cover. The depth of snow necessary to protect soil from freezing will depend, of course, on the air temperature.

For a clearer understanding of the relationship of snow depth to frost, an exploratory study was recently conducted near Laconia, New Hampshire, in which concurrent measurements of air, snow, and soil temperatures were taken and interpreted in respect to each other and to the formation of soil frost.

Methods and Site

Temperatures were measured in the winter of 1960-61 in two level plots in a 30-year-old beech-maple woodlot. The soil was a Shapleigh sandy loam, well-drained and relatively stone-free. The L and F layers in both plots were removed. Three stacks of thermocouples were installed in the soil on each plot at depths of 1/4, 3, 6, 12, and 24 inches. Snow was allowed to accumulate on one plot. On the other, snow was shovelled and swept away after each snowfall.

On the snow-plot, a stack of unshielded thermocouples 3, 6, 12, 18, 24, 30, and 36 inches above the ground gave temperature readings within and above the snowpack. A portable, non-recording potentiometer with temperature adjustment was used; a heating coil around the standard cell kept it operable in sub-freezing weather. A thermograph, 4 1/2 feet above the ground between the plots, provided a continuous record of air temperature. Snow depth and density were measured with a Mt. Rose snow tube.

Results

Soil temperatures at the ¼- and 3-inch depths were affected immediately by snow accumulation, beginning December 15. At the 6-inch depth the snow effect was not apparent until December 26. At the two lowest depths the effects did not appear until January 8—about a 3-week lag. Thereafter soil temperatures under snow varied little, the maximum fluctuation at any one depth being about 3°F. The data recorded are graphed in figure 1.

Within the snow pack there is less fluctuation in temperature than at points nearer the snow-air interface or in the air. For example, air temperatures taken concurrently with snow and soil temperatures ranged from 43° to 4°F. (a difference of 39°); and in snow, 12 inches above the ground, temperatures ranged from 34° to 10° (a difference of 24°). In snow 6 and 3 inches above the ground, the difference was only about 10°.

Air, snow, and soil temperatures and their variation from 19 measurements between December 28 and April 6 are compared in table 1. Here again are shown: higher temperatures both within the snow pack and at greater soil depths, a reduced variation in temperature going from air to snow to snow-covered soil, and a greater variation of soil temperature in the bare plot than on the snow-covered one.

On the bare plot, soil temperatures were influenced by concurrent mean daily temperatures only to a depth of about 6 inches. Air-soil temperature

Table 1.—***Air, snow, and soil temperatures and their variation***

Item	Height above soil surface	Temperatures: Mean	Temperatures: Standard deviation	Coefficient of variation
	Inches	*°F.*	*°F.*	*%*
Air	54	23.4	12.9	55
	12	23.5	7.0	30
Snow	6	28.2	3.4	12
	3	30.2	2.0	7

Item	Depth below soil surface	Mean: Snow-covered	Mean: Bare	Standard deviation: Snow-covered	Standard deviation: Bare	Coefficient of variation: Snow-covered	Coefficient of variation: Bare
	Inches	*°F.*	*°F.*	*°F.*	*°F.*	*%*	*%*
	¼	32.0	26.3	0.5	10.4	2	40
	3	32.6	25.5	.4	5.5	1	22
Soil	6	33.6	27.0	.5	4.6	1	17
	12	35.1	29.9	.6	3.1	2	11
	24	36.9	32.7	1.1	2.2	3	7

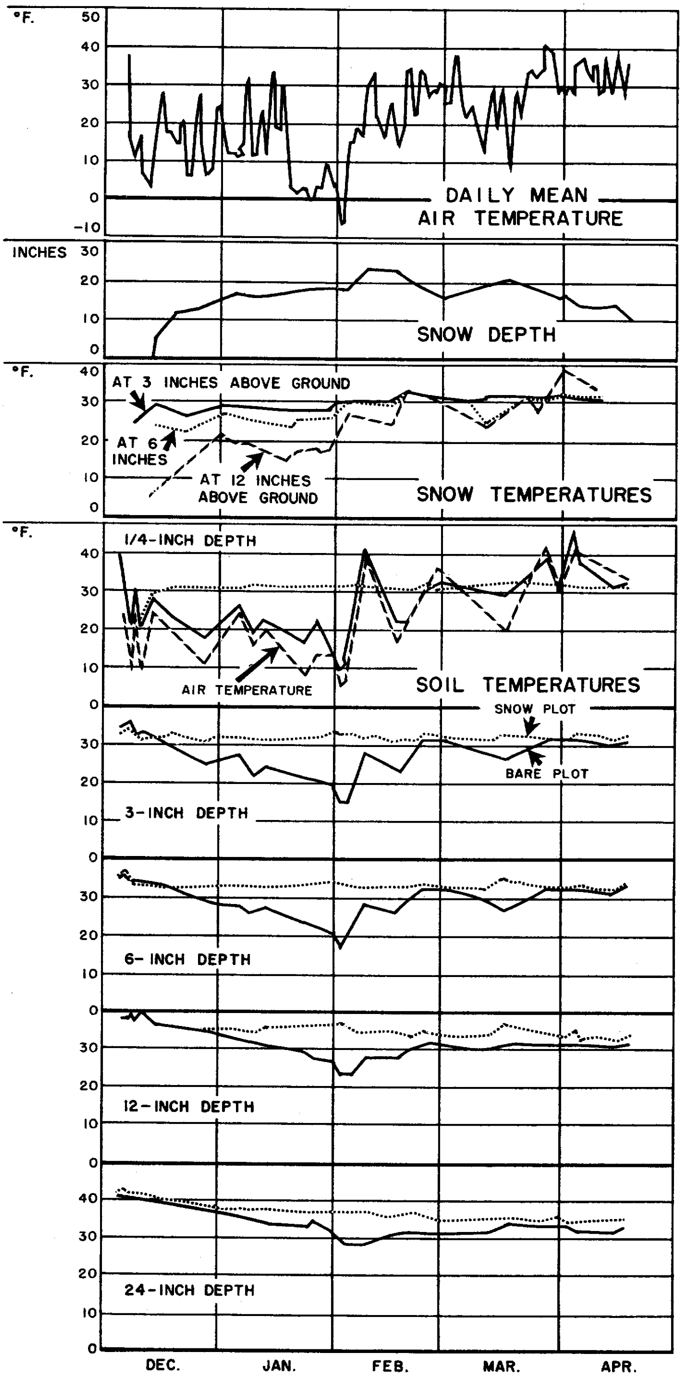

Figure 1. — Air, snow, and soil temperatures and snow depths.

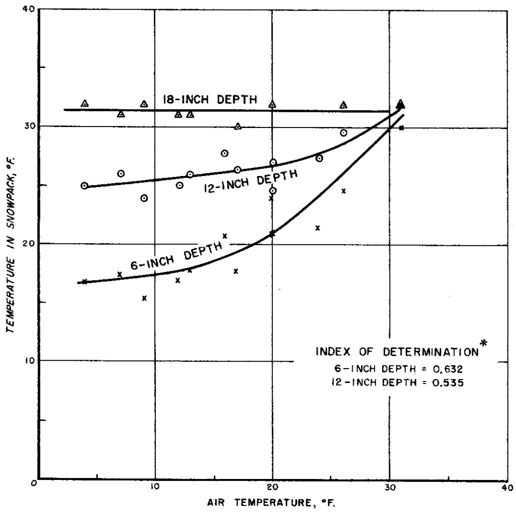

Figure 2. — Temperatures of the snowpack 6, 12, and 18 inches below the surface in relation to air temperature.

***The fraction of the variance in snowpack temperature that is associated with difference in air temperature.**

correlation coefficients for the period were 0.85 at ¼ inch soil depth, 0.63 at 3 inches, 0.49 at 6 inches, 0.16 at 12 inches, and —0.19 at 24 inches.

To determine how much antecedent air temperatures would improve this correlation, mean daily temperatures for antecedent periods ranging in length from 2 to 10 days were determined and their correlation with soil temperatures 3 inches and below was calculated. Correlation increased rapidly up to a 6-day period, with little change thereafter. Correlation coefficients for the 6-day period were 0.85 for 3 inches, 0.76 for 6 inches, 0.51 for 12 inches, and 0.15 for 24 inches.

The relationship of air temperature (average temperature registered by all thermocouples above the snow) to temperatures within the snowpack at 6, 12, and 18 inches is given in figure 2. If freezing at the soil surface occurs at 25°F., as others have reported, then no freezing will occur under 18 inches of snow with air temperatures as low as 4°F. Twelve inches of snow will prevent soil freezing at air temperatures down to 5°F., and 6 inches of snow restricts freezing down to 25°F., under the conditions of this study. These results lend some support to the general observation that snow depths of more than 18 inches will prevent frost penetration of the soil.

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