DISPOSITION OF INTERCEPTED SNOW[1/]

by

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How much snow is intercepted by the crowns of coniferous trees, and what becomes of it? To explore this question we set up a small experiment to measure the amount of snow that conifer branches catch, and the various factors that affect it such as temperature, humidity, and solar radiation. Though our study does not define the processes precisely, it does illustrate the disposition of intercepted snow, and indicates some of the problems involved in determining snow-evaporation losses from tree crowns.

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Much of the effect of forests on the runoff from snow has been attributed, largely by inference, to snow interception by the tree crowns. Direct measurements of amount of snow intercepted by tree branches or crowns have been rare (Lull and Rushmore, 1961; Seppanen, 1959; Forest Experiment Station, Meguro, Tokyo, 1952). The few measurements that have been made indicate that significant amounts of snow may be caught and held on conifer branches for much of the winter season. But they do not indicate that any important portion of the snow held on the canopy is vaporized, as it must be if the intercepted snow is to be considered lost and not merely delayed on its way to the ground or subjected to small scale spatial redistribution.

THE STUDY

Our study was designed to determine the approximate amount of snow intercepted by individual crowns of coniferous trees and its disposition under the climatic conditions of central New York.

For this purpose we selected and cut three 6-foot-tall conifers and stood them in a natural upright position in boxes on platform scales. The boxes (of about 3 cubic-foot capacity) were filled with pea stone to hold the trees in position and were wrapped in plastic to keep snow out. The platform scales had a maximum capacity of 500 pounds and a sensitivity to 1/4 pound (Fig. 1).

A light wooden frame supporting a plastic catchment sheet was placed under the canopy just above the stone-filled box. This catchment device (about 5 x 8 feet) extended beyond the periphery of the crown, and was designed to catch all snow or water falling from the tree.

The situations that will be described in this report include only periods when the wind was insufficient to blow snow off the trees; the results were not invalidated by failure to measure wind blown snow.

Incoming solar radiation was measured with a Moll-Gorczynski type of solarimeter. Net radiation above the tree crowns and within one of the crowns was measured with Fritschen miniature net radiometers. Ambient air temperature and relative humidity were measured with a recording hygrothermograph in a standard shelter. A measure of precipitation was obtained with a recording precipitation gage and snow boards. On occasion a Barnes infrared thermometer was used to monitor the surface temperature of a patch of intercepted snow or to scan periodically the surface temperature of the tree. This instrumentation is not adequate for a rigorous computation of interception loss but does indicate the magnitude of this phenomenon and provides a rough check on the processes involved.

Attempts at measuring the disposition of intercepted snow have been made with this system or a modified form of it since 1962. However, only in the winters of 1965-66 and 1966-67 have useable data been acquired. Supporting the cut tree in a natural manner that would not interfere with repeated measurements has been a problem, as has the requirement for a weighing mechanism of sufficient capacity and sensitivity to detect the small periodic losses with which we were concerned. Measurement is imprecise when wind velocity exceeds 2-4 mph.

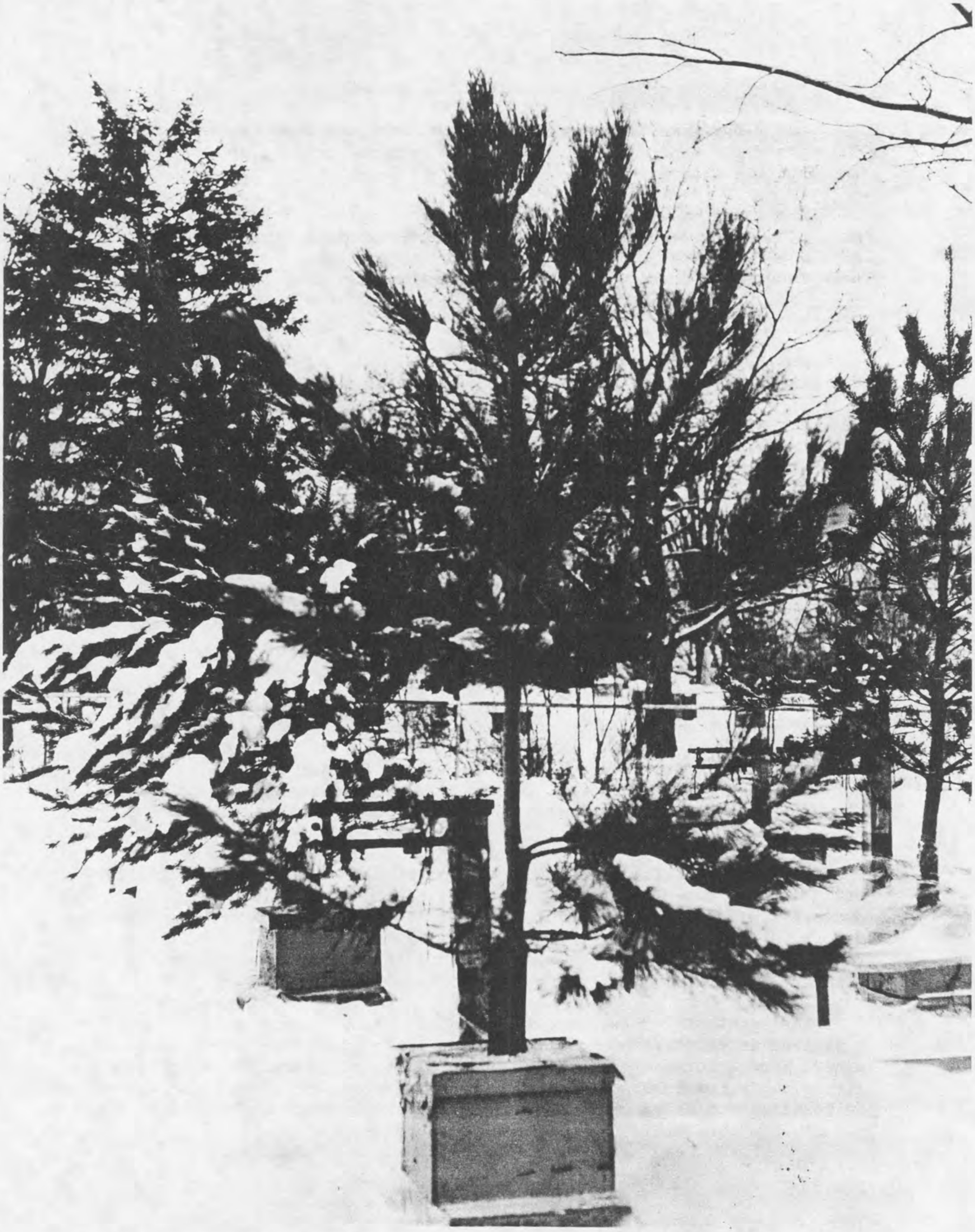

Figure 1.--Experimental installation for snow interception.

ILLUSTRATIVE RESULTS

Two 2-day periods have been selected from the past two seasons to illustrate the method used, the type of information obtained, and some of the problems encountered.

The first example chosen illustrates a typical situation in winter over much of the Northeast. Solar radiation is extremely low and apparently not adequate for the vaporization of much intercepted snow. Temperatures are near freezing and relative humidity is moderately high.

2-3 February 1967

During the night of 1-2 February 1967, 75 mm. (2.9 inches) of snow fell, depositing snow approximately 45-50 mm. deep (1.8 - 1.9 inches) on the branches of the trees. This was the equivalent of 7 to 11 mm. of water over the projected horizontal area of the individual crowns (Fig. 2). Between 0900 and 1100 hours EST on the morning of 2 February sleet and snow added about 3 mm. to that on the ground and about 0.1 mm. water equivalent to the trees.

The amount of snow intercepted by the three tree crowns used appears to be mainly a function of the density of the foliage. The tree that withheld the most snow was a full, bushy Scots pine, whereas the other two were both of medium density, one a Scots pine and one a red pine. Some of the snow was apparently held loosely and dropped off en masse between 1150 and 1320, bringing the two trees of medium density into very close agreement in the amount of snow held.

Wind velocity throughout the day was generally low but occasional gusts helped to dislodge some of the snow on the canopy. Evaporation loss over the day was 0.66 mm., much of it coming in the afternoon when the relative humidity dropped, in spite of the slight decline in temperature. The net radiation above the crown during this period, 5.9 langleys, is sufficient to account for only about 0.1 mm. of the loss. However, net radiation within the crown was 8 langleys during the same period and was sufficient to account for 0.14 mm., of the water loss.

Probably the effective radiation was nearer to total incoming solar radiation for the period, 24.3 langleys, which, if all of it were used for evaporation, could dispose of only about 0.4 mm. Thus it follows that about one-third of the interception losses during this period must be attributed to some other energy source, possibly advected energy or an effective concentration of radiation on tree branches or snow surfaces.

The night of 2-3 February we recorded a drop in temperature as well as a decline in relative humidity. The wet intercepted snow may have acted as a heat source for the evaporation of part of the 1.3 mm. of water lost. A strong vapor pressure gradient away from the snow--as is suggested by the drop in relative humidity--would have withdrawn energy from the system to overcome the non-equilibrium in the air-snow pressure system.

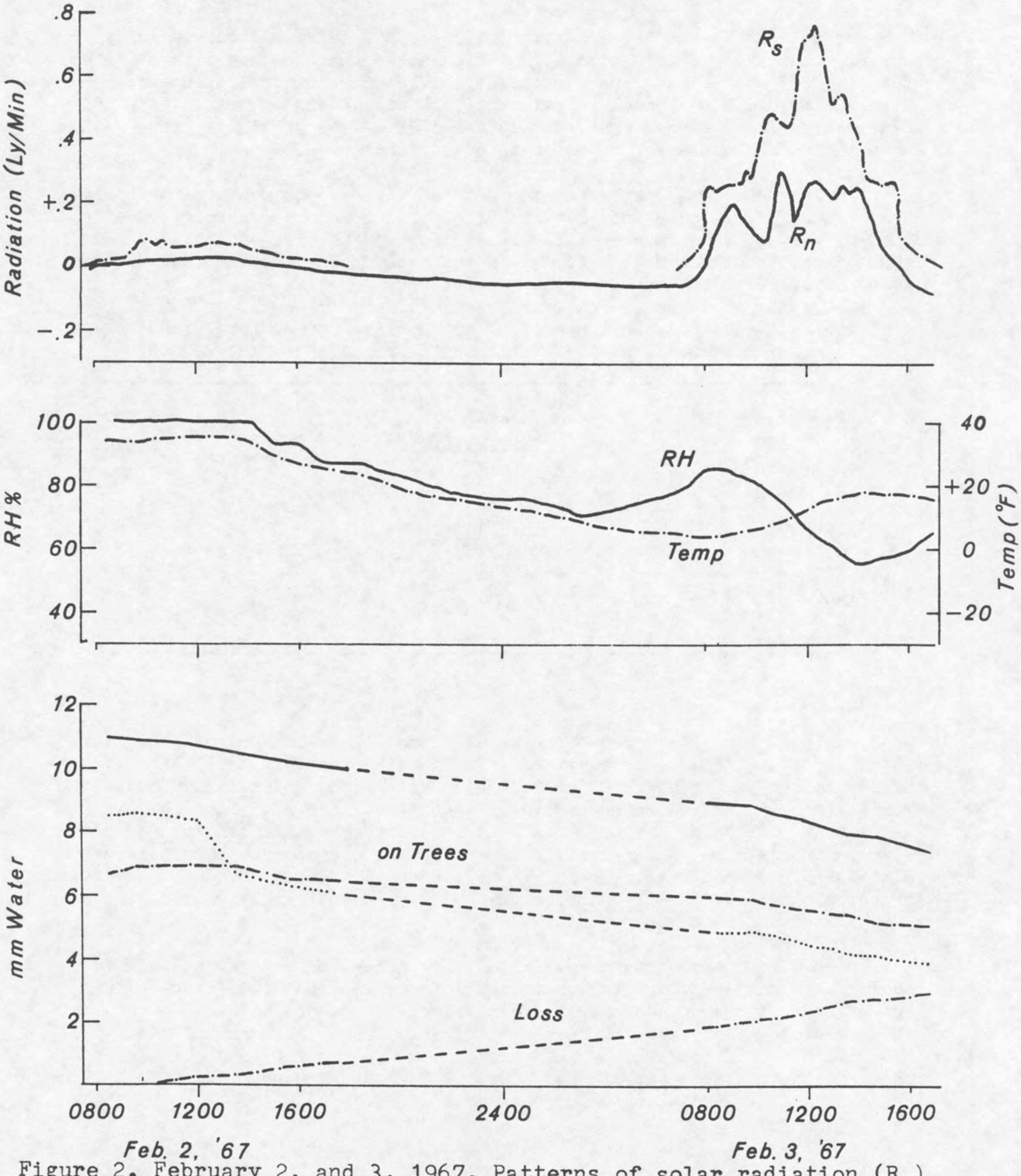

Figure 2. February 2, and 3, 1967. Patterns of solar radiation (R_s), net radiation (R_n), temperature, relative humidity (RH), and intercepted snow.

On 3 February the gross meteorological factors changed considerably from the previous day. Solar and net radiation above the crown were much higher, totaling 187 and 72 langleys for the day. The ambient air temperature remained below 20°F., with a typical temperature-related pattern of relative humidity. Evaporation loss of snow over the day was 1 mm.--well within the potential of even the rather conservative estimate of net radiation.

During the day the infrared thermometer was used to monitor the surface temperature of a single snow-covered branch. Its record generally paralleled that of the air temperature (Table 1), but showed greater variability and rapid fluctuations as heat built up in the tree crowns and then was dissipated by puffs of very low-velocity wind (<1 mph).

Table 1.--Ambient air temperature and surface temperature of a snow-covered southwest-facing pine branch, February 3, 1967.

Time	Air Temperature °F	Snow Surface Temperature °F
0930	6	8
1050	9	16
1150	13	15
1300	16	18
1335	17	19
1445	18	16
1630	16	13

6-7 March 1967

During the night of 5-6 March about 40 mm. (1.5+ inches) of snow fell, of which about 1.06 mm. water equivalent was intercepted (Fig. 3). Air temperature remained in the upper 20's until late afternoon, and relative humidity varied from an early morning high near 100% to a later afternoon low of 73%. Radiation, both solar and net, was low, totaling 75 and 37 langleys respectively for the day. Net radiation was adequate to evaporate almost twice the 0.38 mm. of water actually lost. There was no visible evidence of snow falling or being blown off the trees under the relatively low-velocity winds (less than 4 mph) experienced during the day.

Over night, approximately 45 mm. (1.7+ inches) of additional snow fell, adding 1.28 mm. of precipitation to the intercepted snow remaining in the crowns. We have assumed no loss of intercepted snow due to evaporation, but this should be accepted with some qualification. All branches of the sample trees were equally covered by intercepted snow (including the interior branches) when precipitation ceased at 0945. Over the next 3-1/4 hours 77 and 41 langleys of solar and net radiation were received.

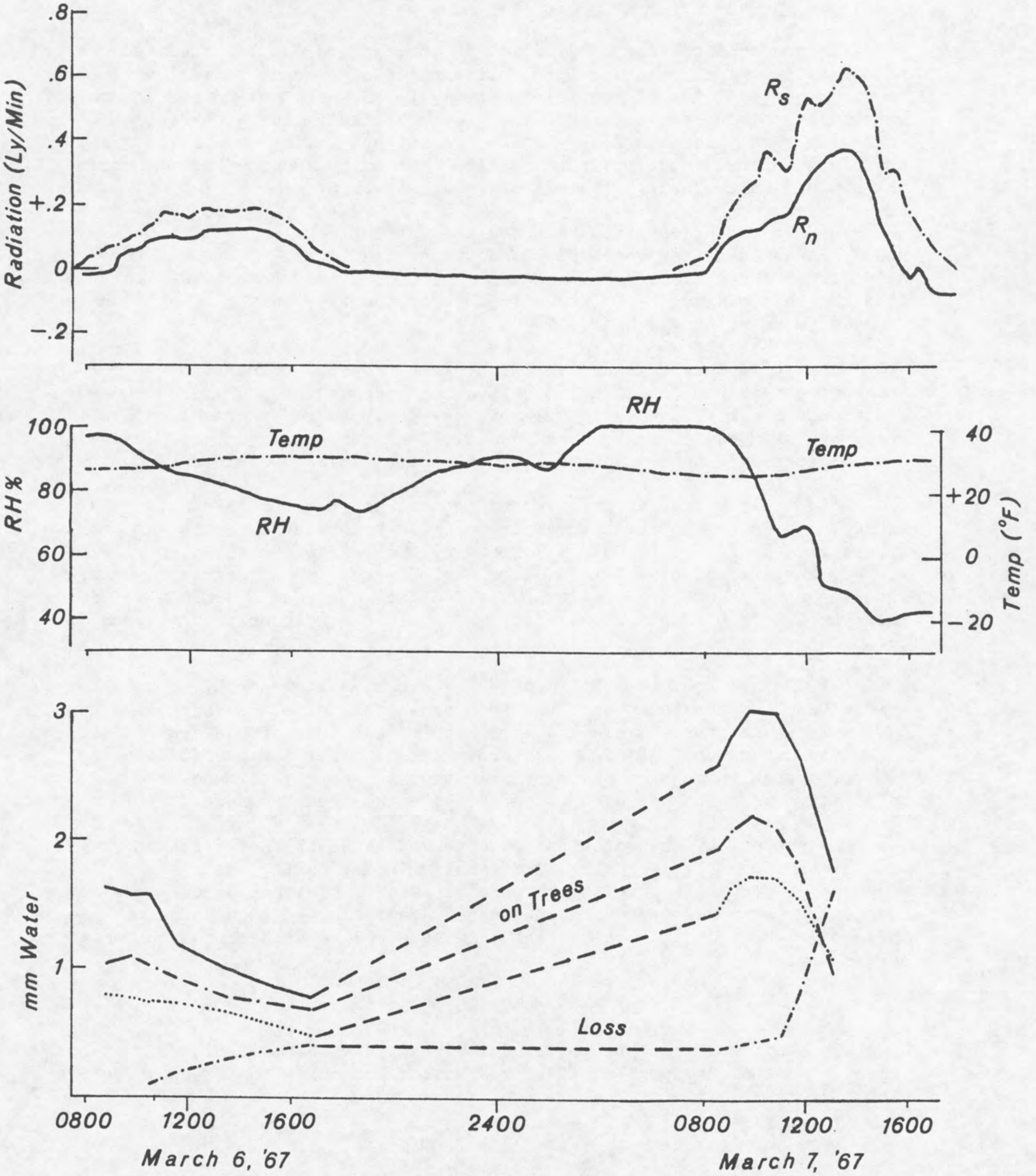

Figure 3. March 6, and 7, 1967. Patterns of solar radiation (R_s), net radiation (R_n), temperature, relative humidity (RH), and intercepted snow.

The evaporation loss of 1.22 mm. in this period can be accounted for by the total incoming radiation but consideration of the net radiation itself requires the addition of sufficient energy to account for another 1/2 mm. of water. Advected energy does not seem to be a likely source, because of the extremely stable temperature. Reduced relative humidity may indicate a sharply steepened vapor pressure gradient away from the snow in the crowns, which would make possible its effective dissipation.

The net radiation measured above the sample trees may be weighted by an unduly large seen area which includes surrounding areas of snow on the ground. Reflected solar radiation measured above a closed snow-covered conifer plantation showed a maximum of 20 percent; most of the time only half that was reflected (Leonard and Eschner, 1967).

Persistent weight gains over night when the snow boards showed no apparent precipitation led us to suspect the adequacy of our weight measurements. To check this we put a plastic-covered box of pea gravel on a similar scale and exposed it to the same conditions as our sample trees. Its weight did not vary over the season, as long as there was no visible snow on its top.

Detectable weight gains occurred on the sample trees on nights when there was no snowfall and the temperature was below 32°F. Frost was not always grossly apparent, but on 7 February 1966, after an overnight low of -20°F., the maximum of 0.5 to 0.6 mm. was observed. This persisted well into the morning until 1030. A more frequently observed overnight weight gain was 0.1 or 0.2 mm. This effect was not detectable on the frequent occasions when snow fell at night.

Temperature profiles within trees measured by thermocouples exposed between needles, indicate that the tree crown acts as a heat sink during the day, with temperatures averaging 4°F. higher than that of the ambient air in the early afternoon. At night the crown can thus act as an effective heat source, probably making a major contribution to the negative net radiation of 30 langleys which has been observed above the tree crowns.

The pattern of snow dissipation observed lends further strength to the idea of the tree itself acting as a sink for solar radiation in the day and a source of very effective longwave radiation. Individual "snow packs" held on the pine branches decreased in depth by shrinking in around the circumference and upward until they eventually appeared to be balanced on the needle tips.

DISCUSSION

Our study was meant to be illustrative rather than definitive. It does indicate some of the problems involved in the determination of snow evaporation losses from tree crowns.

Forms of energy that are usually ignored in gross measurements of climatic parameters involved in snow hydrology have been suggested as causes for the dissipation of intercepted snow. Solar radiation, when it is available at relatively high intensity, is effective in causing evaporation. When it is not, evaporation loss may be caused by longwave radiation from the tree branches, advected sensible heat, and the snow itself when a sharp vapor pressure gradient exists.

Deposition of moisture occurs on the tree crowns on most cold nights and may or may not be visible. It is usually an extremely small amount but may be as large as 0.5 mm. under conditions of extreme cold.

Finally, the system described in this paper works well under a wide range of climatic conditions and is surprisingly sensitive.

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