The Disposition of Snow Caught by Conifer Crowns

DONALD R. SATTERLUND

Washington State University, Pullman, Washington 99163

HAROLD F. HAUPT

Forestry Sciences Laboratory, Moscow, Idaho 83843

Abstract. Snow interception studies during the warm winters of 1966–1967 and 1967–1968 in northern Idaho revealed that Douglas fir and western white pine saplings caught about one third of the snow that fell in 22 storms. More than 80% of the snow initially caught in the crowns ultimately reached the ground being washed off by subsequent rain, falling by direct mass release, or dripping as melting snow. Only a small portion was lost by evaporation.

INTRODUCTION

This paper is a continuation of a previous study in which the development of interception storage of snow on sapling Douglas fir (*Pseudotsuga menziesii* var. *glauca* [Beissn] Franco) and western white pine (*Pinus monticola* Dougl.) was described [*Satterlund and Haupt,* 1967]. It reports on the disposition of intercepted snow to the ground and the atmosphere from seven trees of each species during the period January 10, 1967 to March 27, 1967, and December 4, 1967 to April 8, 1968.

METHOD OF STUDY

The experimental site, recording apparatus, and field procedure have been previously described [*Satterlund and Haupt,* 1967; *Haupt and Jeffers,* 1967]. Basically, a continuous weight record of snow load on suspended trees (an 'interceptograph') was maintained except for two storm periods in December 1967, and January 1968, when records were lost because of instrument malfunction.

The catch, retention, and release of snow by the trees was followed on the interceptograph (Figure 1). During snowstorms, the buildup of the snow load was accompanied by a rise of the trace. Many of the snowstorms turned to rain, or were followed closely by rain. An irregular, declining trace during rain indicated that snow was being washed off the trees. It was assumed, based upon considerations of vapor pressure, that none of the loss during rainstorms was evaporated, and that all the snow released from the trees reached the ground in solid or liquid form.

Snow also fell from the trees en masse after a storm ended, and could be identified by a sharp, vertical trace on the interceptograph. Whenever one pound or more of snow fell we could measure the quantity directly from the trace. We refer to these directly measured quantities of snow released from the trees as 'large mass release.' Snow also fell from the trees at intervals too close, and in quantities too small, to measure individually from the interceptograph. During periods of above-freezing temperatures, drip from melting snow on the branches often accompanied the release of small masses of snow. Either way the snow fell resulted in an irregular decline in the trace. We call the release of water from the trees which is too small in quantity to measure individually (whether as snow, drip, or both) 'minor mass release.'

Minor mass release was often accompanied by conditions conducive to evaporation, and frequently extended over periods of several hours or more. Though the total loss of water from the trees could be measured from the interceptograph during such periods, the amount that reached the ground and the amount that evaporated could not. Therefore we measured the quantity reaching the ground by catching it on a large plastic sheet spread below the trees and weighing it directly. The difference between

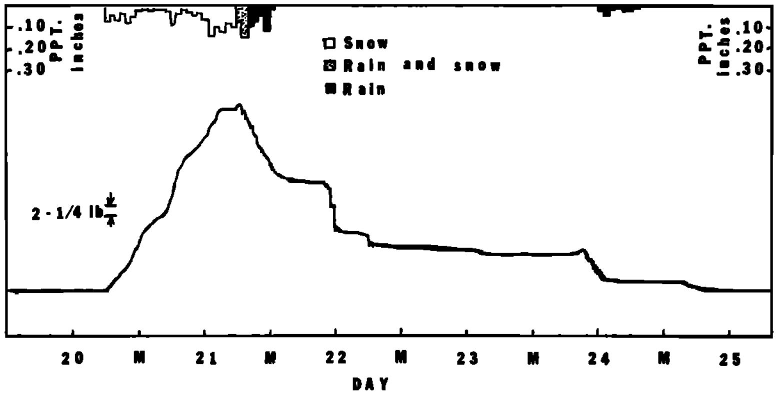

Fig. 1. A composite interceptograph combining portions of several actual interceptographs to illustrate different aspects of the snow interception water balance. Days 20 and 21: snow begins and accumulates on the bare tree. As the storm turns to rain, part of the intercepted snow is washed to the ground. Day 22: warm temperatures result in minor mass release (irregular decline) and large mass release (vertical trace) of snow. Day 23: slight decline due to evaporation of intercepted snow. Day 24: rain washed remaining snow from tree leaving it bare and wet. Day 25: liquid water evaporates leaving tree bare and dry.

the amount lost from the trees, as revealed by the interceptograph, and that caught on the sheet was attributed to evaporation.

The measurements of minor mass release to the ground were frequently nullified by additional precipitation. Consequently, we were forced to estimate its quantity by extrapolating our few successful measurements over the entire period that minor mass release occurred. Temperature, wind, humidity, and radiation records were checked against the interceptograph to delineate the periods when minor mass release and evaporation were concurrent.

Evaporation during periods without mass release could be identified by a slow, regular decline of the trace but occurred with surprising infrequency. Less than one third of the snowstorms were followed by one or more identifiable periods of evaporation without concurrent mass release.

RESULTS

The weather during the winters of 1966–1967 and 1967–1968 was warm and moist, and unfavorable atmospheric conditions for evaporative losses of intercepted snow predominated. Precipitation was much above normal in the 1966–1967 season and near normal during the 1967–1968 season, but most of it occurred as rain. Only 22 snowstorms, with a water equivalent of 8.65 inches, were sampled. The records from two major snowstorms, with a water equivalent of 2.33 inches, were lost because of instrument malfunction in the 1967–1968 season. A complete tabulation of the disposition of intercepted snow is presented for each tree species in Table 1.

Only about one third of the snowfall was temporarily retained in the tree crowns at the end of snowfall. Losses back to the atmosphere from intercepted snow represented only 4.5% and 5.2% of total snowfall for the Douglas fir and white pine, respectively.

Most of the intercepted snow (86% of the initial catch) ultimately reached the ground. The greatest quantity (about 46%) was washed off by rain. Large mass release of snow from the branches accounted for an additional 25%, and minor mass release and drip from melting snow in the branches accounted for the remainder.

No important quantitative differences in total snow catch or in the mode and timing of loss of snow from the crowns were evident by species. Though no statistical tests were undertaken, the obvious storm-to-storm variability in catch and loss insures that the small differences in Table 1 are not significant.

DISCUSSION

Despite the rather great differences in form, needle structure and arrangement, branch stiff-

TABLE 1. The Disposition of Intercepted Snow from Douglas Fir and Western White Pine Saplings at the Priest River Experimental Forest (winters of 1966–1967 and 1967–1968)

	Douglas Fir		White Pine	
	Water Equivalent, inches	%	Water Equivalent, inches	%
Total snowfall	8.65	100	8.65	100
Gross interception storage*	2.78	32.1	3.07	35.5
Throughfall during storms	5.87	67.9	5.58	64.5
Snow washed off by rain*	1.33	15.4	1.36	15.7
Large mass release to ground*	0.68	7.9	0.80	9.2
Minor mass release and drip to ground†	0.38	4.4	0.46	5.3
Total to ground	8.26	95.5	8.20	94.8
Evaporation*	0.13	1.5	0.15	1.7
Evaporation during minor mass release and drip†	0.26	3.0	0.30	3.5
Total evaporation loss	0.39	4.5	0.45	5.2

* Measured directly from interceptograph.
† Estimated on basis of sample measurements.

ness, and other characteristics of Douglas fir and white pine crowns, there was little difference in either their catch or release of snow. This suggests that meteorological conditions rather than morphological characteristics of the trees themselves dominate in the interception of snow from evergreen conifers of similar size. The dominance of the meteorological factor is further indicated by the similar timing of snow losses by both species to the ground by rainwash, mass release, and drip.

The evaporative losses from snow interception were surprisingly small from either an absolute standpoint or relative to total snowfall. Several factors are involved.

Instrument malfunction during two storm periods when a total of nearly 2½ inches, water equivalent, of snow fell prevented measurement of more than one fifth of the total snowfall; thus, the absolute measure of loss is less than the actual loss. However, since the proportion of intercepted snow released to the ground, particularly by rainwash and large mass release, was greater following heavy storms than light storms, the percentage of evaporative loss may be slightly overstated.

Further, the estimates of minor mass release and drip reaching the ground contain an unknown amount of error. But even a substantial error in partitioning between the ground and the atmosphere could not change the essential conclusion of a small evaporative loss from snow interception.

The primary cause of the small evaporative loss was the warm, moist winter weather at low elevations (2400 feet, MSL) at the Priest River Experimental Forest. This is evidenced by the substantial removal of snow from the crowns by rain and by the large mass release that almost always occurred during above-freezing weather. (The mechanical action of wind in this protected valley site was not important to either catch or release of snow).

The small evaporative loss from intercepted snow supports the observations of *Miller* [1962] in the Sierra Nevada of California. He concluded that warm daytime temperatures, which were accompanied by the rapid release of snow by mass release and drip, sharply limited interception losses. However, such results may not be representative of somewhat cooler and drier conditions, under which snow may persist on the trees exposed to evaporative losses for much longer periods of time. Snow seldom remained on the trees for more than a day or two after each storm, so caution must be used in extending these data to colder climatic conditions.

Though mass release of intercepted snow or drip to the ground is the major factor in the small interception loss, the slow accumulation of interception storage at the beginning of snowstorms is another. Unlike rainfall, small storms contribute little to snow interception losses, for throughfall is high during the early stages of each storm [*Satterlund and Haupt*, 1967].

The negligible catch of snow in small storms, combined with the rapid mass release of snow or drip to the ground following large storms, was sufficient to eliminate most opportunity for evaporative losses to occur in this study. The dominance of the meteorological factors also masked differences between the Douglas fir and western white pine which might have been expected in view of their considerably different crown morphology.

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REFERENCES

Haupt, H. F., and B. L. Jeffers, A system for automatically recording weight changes in sapling trees, 4 pp., *U. S. Forest Serv. Res. Note INT-71,* Intermountain Forest and Range Experiment Station, Ogden, Utah, 1967.

Miller, D. H., Snow in the trees—Where does it go?, *Proc. 30th West. Snow Conf.,* 21–27, 1962.

Satterlund, D. R., and H. F. Haupt, Snow catch by conifer crowns, *Water Resour. Res., 3*(4), 1035–1039, 1967.

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