SNOW IN THE TREES -- WHERE DOES IT GO?

By

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Snow-covered trees are familiar in the winter scene, but where that snow goes is not so clear. We are acquainted with the sight of snow drifting, falling, blowing, and sliding off trees, and of water dripping to the ground. We can picture the invisible flow of vapor from the intercepted snow, but we have little information on how much snow, water, or vapor arrives at the several destinations or how they get there. Some intercepted snow reaches the snow mantle on the ground beneath the tree or in nearby openings as flakes, chunks, and partly-melted pieces. Some meltwater moves quickly into the soil and the ground water. Some of the vapor condenses on the snow suface beneath the canopy, and some is diffused aloft and carried far away. But we have a hard time saying how much of the snow intercepted by trees when a snowstorm sweeps over a forested basin will end up in each of these destinations.

We do not have measurements of snow, water, or vapor reaching each destination. Thus we are forced to examine the mass-transport processes that move intercepted snow and to infer destinations from the relative importance of each process in a given situation. There are a few measurements in the crown zone of the forest, where these processes begin. [2] There also are verbal accounts, more numerous than are quantitative data, about the processes in action. It is difficult, however, to tell which processes are hardly more than annoyances to a man in the field and which move significant amounts of snow or water.

These transports of snow, water, and vapor are often over only short distances, but they are important segments of the hydrologic cycle and will eventually be subjected to measurement in the laboratory, in the wind tunnel, and at the microclimatological study site. Pending such investigations, it is worthwhile to make some analyses and comparisons of the existing fragmentary data. My experience in the Sierra Nevada and in New England suggests similarities and differences in the mass-transport processes. In comparative analysis the diverse viewpoints of the various field investigators who have published their ideas is an advantage. We are aided in forming a general outline of how snow moves from tree crowns and where it goes by concepts develoned in forest microclimatology and heat-balance research on snow.

TRANSLOCATION OF INTERCEPTED SNOW

Before leaving the tree crown, snow may move to another location than where it first came to rest. For example, when snow falls to a lower branch or creeps out along a sloping branch, it becomes more or less vulnerable to subsequent action by the mass-transport process that will move it from the tree. Meltwater flows away from its parent snow mass, spreads in a film, collects into drops, or forms streams, depending on the growth habit of the tree and the microdistribution of heat. When meltwater moves into a colder microclimate and refreezes, it cements a snow mass to the branch, or forms an icicle below the branch. Translocation also occurs inside a snow mass, when liquid or vapor moves under the influence of gravity or vapor-pressure gradient. This action may make the mass more stable on its support or more susceptible to melting than before.

MECHANICAL TRANSPORT

Wind and gravity are mechanical forces acting on snow masses in trees. These forces are opposed by cohesion among snow particles and their adhesion to their supports. Fresh snow often has low cohesion and much of it falls. Some authors report that most snow moving from the crowns does so by falling (Jaenicke and Foerster 1915; Church 1934; Hildebrand and Pagenhart 1954). Direct action of wind detaches snow particles and erodes snow masses; indirect action vibrates trees and shakes snow loose. For example, Wellington (1950) credits the vibration of deciduous trees for the small snow loads they bear.

In one experiment (Japanese Government Forest Experiment Station 1952), continuous weighing of a severed cryptomeria tree (an evergreen with flexible branches) during and after snowstorms indicated a critical wind speed for blowing snow at about 3 meters per second. This wind removed half the snow load in a few hours. A rise of wind from calm to 1 meter per second reduced the snow load on a pyramidal model by 40 percent, on the tree by 25 percent.

Snow in crowns of a forest stand is less vulnerable to wind than these experiments suggest. In some stands, wind alone cannot move all the intercepted snow. Pruitt (1958) found that moderate strong winds caused little attrition of intercepted snow in Alaskan spruce. In a recent study, the blast from a helicopter (Cramer 1960) cleared only the top 2 or 3 meters of a canopy and did not touch snow on lower branches. Just as Grah and Wilson (1945) found that shaking could not remove all the water on foliage, Goodell (1959) reported that shaking removed only two-thirds of the amount of cold dry snow in a branch, Lull and Rushmore (1961) found a quarter of the initial snow load remaining on artificially-supported branches after windy weather. Wind action is often incomplete if heat is lacking. If a strong wind does not follow a snowstorm, snow masses in trees become cohesive and resist mechanical removal.

Intercepted snow that is removed by wind before becoming cohesive is blown off trees

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[2] Church (1934) made some measurements with evaporation pans in trees in 1915 and 1917.

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in small chunks or flakes into gaps between trees or into larger openings. For example, Jaenicke and Foerster (1915) reported that most intercepted snow blew into openings of the ponderosa pine forest. Effects of this mass transport on the accuracy of precipitation gages are well known. Intercepted snow falling under the influence of gravity without wind action may drop in large pieces under and near the tree and crater the snow on the ground.

MECHANICAL-THERMAL TRANSPORT

The removal of snow from tree crowns by mechanical forces is often helped by partial melting that frees small or large masses from their hold on the foliage or branches. This movement has not often been measured, although field men have seen and directly experienced snow masses that slide off branches and silently plunge to earth. One cource of data is the Japanese experiments (1952), in which rapid loss of weight of the snow load on the cryptomeria tree (as much as 10-mm. water equivalent in a few hours) probably represents sliding of snow masses that had been clinging to the sloping branches. This load loss was usually associated with above-freezing air temperature and moderate intensity of solar radiation, but the two factors are hard to separate. The change in weight was usually uniform with time. In an average of several cases with snowfall of 1 mm. per hour, a weight decrease of 1 mm. per hour after sunrise indicates a snow-transport rate of about 2 mm. per hour. Higher rates occur after storms, especially if sunshine is strong.

The uniform change in weight with time means that as the snow load in the tree gets smaller, the percentage rate of loss of snow load increases. I calculate from the Japanese data that the hourly rate of removal of snow in conditions favoring melting and sliding was at first about 15 percent of the load, and that the rate increased after a few hours to 30 to 40 percent. This acceleration reflects progressive loosening of bonds holding snow on the sloping branches. It may also indicate that as foliage is freed from snow, it absorbs more solar radiation and heats the surrounding air and snow. Sunshine is also absorbed by foliage beneath the intercepted snow (Church 1942).

Removal of intercepted snow by sliding is thermally efficient, because melting part of the snow frees the whole mass. From the Japanese weight data, we can calculate the heat required to move snow held on flexible branches that are deformed to a sloping attitude when loaded.

I assume that most of the heat is supplied by insolation, whether absorbed by the snow or the foliage, and that little advective heat is involved. From observations at the Central Sierra Snow Laboratory in central California (U. S. Army Corps of Engineers and U. S. Weather Bureau 1952) median insolation during winter snowstorms is found to be 10 langleys per hour, to account for slant radiation on a free-standing tree. From aerial observations reported by Barashkova (1961), I take the albedo of a tree bearing fresh snow as 0.5, giving absorption of 7.5 langleys per hour. Assuming net loss of heat by exchange of long-wave radiation between tree crowns and clouds and ground as -2 langleys per hour during the storm, the net surplus of radiation for the crown-projected area is 5.5 langleys per hour. This amount of heat would melt 0.7 mm. water equivalent of snow hourly. The hourly change in weight of snow load during a snowstorm, as noted earlier, was 2 mm. Thus, if all available heat is applied to the melting process, a third of the snow leaving the tree is melted and two-thirds slides off unmelted. It is likely that this fraction is an upper limit, and that less than a quarter of a large snow mass is melted when it slides off.

A graph (Japanese Government Forest Experiment Station 1952, p. 146) of weight change plotted against accumulated insolation is enveloped by a line having a slope equal to 1 percent loss of snow load per langley insolation. Thus a 20 mm. snow load would lose 2 mm. in an hour with 10 langley insolation during a snowstorm, and 5 or more mm. water equivalent per hour after the clouds clear away. These rates apply to an exposed tree, not a forest stand. Church (1934) found that his tree pans, which were intended to measure evaporation from intercepted snow in forests near Lake Tahoe, caught large amounts of dripping meltwater and part-melted snow. In the same area, Hildebrand and Pagenhart (1954) reported that most of the intercepted snow fell as drip and in small chunks. In a denser forest, the rates of dripping and falling might be slower, because the sun strikes only the tree tops.

Insolation alone can make the sliding-falling mass-transport process operate effectually and rapidly. But heat supplied to intercepted snow by convection and condensation from warm moist air during a rainstorm or other period of warm advection -- a thaw -- accelerates the process. By extrapolating the standard formulas for heat transfer from atmosphere to snow on the ground (U. S. Army Corps of Engineers 1956) to account for the greater surface area of intercepted snow masses, I estimate that 8 or 10 mm. water equivalent of snow can be melted or released to slide or fall per hour in advection of moderate intensity. Judging from Pruitt's (1958) graphic description of the noise as chunks of partly-melted snow fell from the branches of an Alaskan forest in a mid-winter thaw, such high rates of release of snow can occur where advection is the principal heat source.

The destination of partly-melted snow masses that slide or fall off the branches is the snow mantle beneath, because they are too heavy and dense to be blown far. There is probably a concentration at the periphery of the crown or within it, if the tree's branches are pulled down by snow loads.

MELTWATER

Intercepted snow consumes the most heat when it stays on tree crowns until completely changed to liquid or vapor. The product is more fluid or mobile and may reach a different destination than does snow leaving the crowns.

Meltwater leaving trees as stemflow does so in amounts believed to be small in conifers, possibly moderate in deciduous trees. Claims in the literature that stemflow does not occur from snow seem much to sweeping. From data published by Rowe and Hendrix (1951) from a long study in the lower part of the Sierra Nevada and by Delfs (1954) in northwest Germany, I calculate stemflow as about 1 mm. per storm. Both sets of data are from maritime climates, in which stemflow is more likely to occur than in dry climates. In such climates, a layer of air that extends from several feet to several hundred feet above the earth's surface is often warmer than 32 degrees F. during and after snowfall. The snow falke that gets through this hazardous warm layer to the snow mantle on the ground is safe, but the flake detained in the warm layer by a tree branch may be melted.

Stemflow concentrates water into a small area, especially if the water is channeled from the trunk to the large roots and more or less directly to ground water. This flow returns to active particpation in the hydrologic cycle much sooner than does snow accumulating on the ground.

Meltwater on branches that do not lead downward to the tree trunk forms into drops that fall off ends of branches and needles, but reports of its quantity are inconsistent. May verbal accounts speak of drenching amounts ("like a showerbath") Jencks (1955), after observing intercepted snow in Oregon, calculated in a water balance of a storm that 6 mm. of meltwater from intercepted snow reached the ground in 2 days. On the other hand Kittredge (1953) in measuring drip pans at a moderate elevation in the Sierra reported that drip and falling snow were minor in some storms, absent in others. I am not sure whether we overestimate drip because it is a nuisance when working in the field, or underestimate by our sampling techniques.

In continental climates, as contrasted with maritime, snowstorms in polar air masses are followed by cold weather, and melting is not common. For example, intercepted snow in the Allegheny Plateau region melts only during thaws, according to Muller.3/ Many authors report no stemflow or drip in such regions, although processes that are so intermittent and variable might sometimes by overlooked.

Drip water is less concentrated than stemflow, but may wet the snow cover rapidly, and in some cases pass through it into the soil. At a time when snow cover in the open is not melting, the snow under the trees that receives large amounts of drip becomes much wetter and denser than before, and approaches it s own melting more rapidly. To the extent that stemflow and dripping meltwater may bypass the snow on the ground, they may accelerate arrival of peak stemflow (Delfs 1955).

EVAPORATION

Evaporation or sublimation is another thermal mass-transport process moving intercepted snow from tree crowns. It does so at a much greater expenditure of energy than melting requires. Evaporation is often considered the most important mode of removal, partly because intercepted snow seems vulnerable to sun and wind attack, and partly because we may, perhaps, overestimate a flow that is invisible and unmeasured. As to attack by sun and wind, Church (1942) pointed out that these agents -- to which evaporation is often ascribed -- often cause intercepted snow to fall or drip. As to measuring vapor flux from intercepted snow, we can only hope that methods developed for measuring flux from such simple surfaces as reservoirs and under development for such surfaces as transpiring crops will be improved until they can be applied to a rough forest surface, for both transpiration and evaporation of intercepted rain or snow. The residual of a series of uncertain volumetric data is also uncertain (Miller, 1961a), because estimating evaporation as the difference between measurements of snow accretion on the forest floor and in openings involves two sources of error (U. S. Army Corps of Engineers). Therefore, this indirect method is not a reliable substitute for measurements of vapor flux. Another indirect method of estimating vapor transport from intercepted snow uses the relationships between evaporation and heat supply and between evaporation and vapor pressure. These two independent meteorological relationships are particularly useful for determing the probable maximum rates of evaporation.

Snow in open sites, exposed to wind and sun, was long believed to vanish mostly by evaporation. But the meteorological conditions of heat supply and humidity gradient suggest that this belief should be questioned. Furthermore a large number of measurements by evaporation pans over the past 20 years throw more doubt on it. In winter, evaporation from snow is limited by lack of heat, and in spring by humidity of the atmosphere, the mass exchange usually going over to condensation by May. Do these two meteorological criteria also apply to the problem of evaporation of snow in tree crowns?

Heat for evaporation -- 680 calories per gram water equivalent or 680 langleys per cm. water equivalent on an areal basis -- has two sources: a surplus in the radiation budget, and advection of sensible and latent heat. Heat from the radiation budget is the principal source

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3/ Muller, R. A. The effects of farm abandonment and reforestation on water yield on the Allegheny Plateau, New York. 1962. (Unpublished doctor's thesis on file at Syracuse University Library, Syracuse, N. Y.)

in some climates.

The daytime radiation budget of an open snowfield in winter is usually small -- even at latitudes as low as those of the Sierra Nevada. At midday, the net gain is estimated at 6 langleys per hour (Miller 1955, p. 154). Part of this gain has to be spent to warm the snow from the cold of the preceding night. On the other hand, the radiation budget of conifer crowns, because of their high absorptivity, shows a large surplus, estimated (Miller 1955, p. 109) as 23 langleys during a midday hour in winter. This surplus warms the air and is partly transported to snow on the ground.

The radiation budget of pine crowns that are partly snow-covered is probably intermediate between the two figures cited. By making use of measurements from several sources, it may be estimated in the following manner, with assumptions conservative so as to give the largest estimate of radiative surplus: (a) Take 50 langleys as insolation during a midday hour of a nonstorm day in winter at the low latitude of the Sierra Nevada (U. S. Army Corps of Engineers and U. S. Weather Bureau 1952, p. 34) (b) assume that two-thirds of this falls on the forest crowns, and that one-third penetrates to the forest floor, of which a quarter, reflected upward, is absorbed by the crowns (Miller 1955, p. 91) (c) take albedo as 0.4 for insolation incident on the crowns, from aerial measurements of albedo of pine forest with fresh snow in parts of the canopy (Barashkova 1961); and (d) assume a net loss of heat by long-wave radiation exchanged between crowns and sky as -5 langleys per hour, and by long-wave radiation exchanged between crowns and the snow on the ground as -2 langleys per hour. The probable maximum radiative surplus is 16 langleys. At higher latitudes and at higher albedos (Barashkova reports values up to 0.55), the net gain would be much less.

If a third of the net gain at midday goes to warm the trees, snow, and local air from the chilling that resulted from the negative radiation budget the night before, 10 langleys remain. How this is divided between melting and evaporating the snow depends on atmospheric humidity and temperature. In the low-latitude anticyclonic climate of the Sierra, air temperature is close enough to 32 degrees F. so that snow would be warmed to the melting point by midday, and in melting would consume, perhaps a quarter of the available heat, leaving 8 langleys for evaporation. This midday rate of 8 langleys per hour heat supply supports about 0.12 mm. per hour water equivalent of evaporation. Daily evaporation probably would not exceed 0.7 mm.

Church (1934) measured evaporation of snow in pans hung in tree crowns that probably were partly snow-covered. In February and March, when he did this work, the midday radiation surplus of the crowns can be estimated from analogy with the foregoing situation as 25 to 30 langleys per hour,which if all devoted to evaporation, would support a rate of 0.4 mm. per hour. However, we do not know how large a source area contributed heat to the suspended pans. Church's data average 1.5 mm. daily evaporation, which is consistent with the calculated rates. This figure was triple the evaporation from pans in the snow on the ground, and illustrates the effectiveness with which foliage absorbs insolation and transmits the surplus heat to adjacent snow.

The Allegheny Plateau lies at a higher latitude than the Sierra Nevada and has a colder winter. In forests there Muller[4] developed a radiation budget for intercepted snow that may be compared with the foregoing. Converted to a midday-hour basis for a clear day in January, it is: (a) insolation 38 langleys per hour as a maximum value; (b) transmission through crowns of a closely-spaced conifer plantation, 20 percent; (c) albedo, 0.40; and (d) net loss of heat by longwave radiation exchange with sky and snow on the ground, -8 langleys per hour. Net gain of radiative heat is 12 langleys per hour by snowy tree crowns, contrasted with 1 langley per hour by snowfields on cultivated land. After a small deduction for heat to warm the local air and the snow in the crowns, Muller applied all remaining heat to evaporation, none to melting, and arrived at a maximum daily rate of evaporation of about 0.7 mm. water equivalent. This is the same rate as in the Sierra Nevada, where a larger gain from radiation is partly expended in melting snow.

In neither of these cases was any income of heat at midday from advection postulated, because atmospheric data indicated it as unlikely. As a matter of fact, warm air from outside the local area is usually warmed by a wet surface, such as the ocean, in winter and, except in a föhn situation, will have a vapor pressure exceeding 6.1 mb. This amount is the maximum vapor pressure that snow can attain. Condensation occurs, not evaporation.

The limit imposed by atmospheric humidity on the evaporation of snow does not apply to evaporation of meltwater separated from its parent snow mass; for if energy is supplied, water can be heated to a temperature at which its vapor pressure exceeds common values of atmospheric vapor pressure. Meltwater on foliage adjacent to a mass of snow has been observed to evaporate rapidly (Church 1934). However, in my field experience these situations occur only where the radiation budget is highly favorable, as on the south sides of crowns of exposed trees. As Goodell (1959) noted, some of the many surfaces of bodies of intercepted snow in such trees will face the sun directly.

On a square-mile basis, evaporation of snow and meltwater is likely to be significant chiefly in the hot-dry advection of a föhn situation. I know of no observations of rates of heat supply to snow during föhn of the stronger kinds, but have calculated heat supplied from subsiding air to the higher ridges of the Sierra Nevada (Miller 1955, p. 73) when upper-air streamlines are curved anticyclonically, as about 50 langley per day, with the rate being perhaps smaller by day than at night. Strong föhn would perhaps double or triple this rate

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[4] op. cit.

for a brief period, producing the spectacular rates of evaporation often remarked by field men. Often the large advective heat supply is joined by a great surplus of radiation during the daytime. The low vapor pressure of the descending Superior air in free föhn or the descending leeward flow in topographic föhn allows most of the large heat surplus to be devoted to evaporation.

For practical hydologic purposes, the whole area of a drainage basin, valleys, and north slopes as well as high south-facing ridges; all the tree canopy, lower and north sides, as well as south sides of crowns; and nonföhn as well as föhn days of the month should be considered. In most snow-bearing forests of the world, the two meteorological criteria limit evaporation of intercepted snow to about a millimeter per day. In the warmest, driest, and sunniest forests, all days averaged together, and heat devoted to evaporation rather than melting, the meteorological conditions limit evaporation to 2 to 3 mm. per day (Miller 1961b).

Direct measurements of vapor transfer itself are much needed. Such measurements would also provide information on the destination of vapor from intercepted snow, because we have no data on how much diffuses back into the atmospheric circulation and how much diffuses downward and condenses on the cold snow surface, perhaps in the same drainage basin. Qualitative observations of condensed vapor on a snow cover suggest that downward vapor flux is not uncommon. In basins where trees serve as surfaces with vapor pressure exceeding 6 mb., the daytime rise of dewpoint in the local air also suggests a flow of vapor from trees to snow on the ground. At the least, the vapor from snow evaporating in the trees inhibits evaporation of snow on the ground.

I have discussed the heat and humidity criteria for evaporation of intercepted snow at some length, because such evaporation is easily exaggerated and because these criteria account for the fact that snow in trees under conditions that seem conducive to evaporation, as in the dry air of the Arctic, actually evaporates so slowly that much of it remains in the crowns for days and weeks.

EFFECTS OF CLIMATE ON MASS-TRANSPORT PROCESSES

To further our understanding of the mass-transport processes that move intercepted snow from forest crowns, we can examine climates in which these processes are inactive or operate more slowly than the rate of deposition of snow by successive storms.

One such region is central Alaska. There the radiation budget of a snow-covered tree crown must be negative even at midday, because insolation is very small. Advective heat comes only in occasional thaws. Intercepted snow rapidly becomes cohesive and resistant to wind erosion. As a result, snow remains in spruce crowns for a month or more, according to daily observations by Pruitt (1958). In northern Manitoba, snow in trees is a sign that the spring thaw has not yet arrived and that snow on the ground is still loose (Pruitt 1959). Again the radiation budget there is small. In the Russian Arctic also, intercepted snow suggests that mass-transfer processes are inactive.

Intercepted snow in lower-latitude forests in fresh polar air masses in winter has a small radiation surplus and is subject to occasional thaws. However, where snowstorms often rage, as in the lee of the Great Lakes, a given period between storms may not experience a thaw. The small radiation surplus, mostly devoted to evaporation, moves only small amounts of snow; hence snow in tree crowns is reported over much of the winter (Lull and Rushmore 1961) 5/.

Mountains may afford shelter from warm advection and wind, and on their north slopes the radiation budget may be negative. The dry air of high elevations favors the thermally inefficient mass-transport process of evaporation. It also reduces the rate of snow removal from tree crowns. Intercepted snow remains for long periods on these high north slopes in Colorado (Goodell 1959).

In cool, cloudy maritime air whose temperature and vapor pressure are about the same as that of intercepted snow, advective heat exchange is minor and the radiation surplus is small. Intercepted snow is likely to hold over between the frequent storms, and this condition is reported from Oregon by McClain (1954) and Jencks (1955), and from uplands of northern Finland.

In these four climates, and perhaps others as well, persistence of snow in forest crowns indicates slow operation of the mass-transport processes, either mechanical or thermal. Wind force is weak compared with cohesion of the intercepted snow, the radiation budget has a small surplus or none, and advective heat supply is small because air warmer than the intercepted snow does not often invade the region. In some of these areas, a small surplus of heat may exist but be inefficiently used up for evaporation. The mass-transfer process requires greatest expenditure of heat per gram transported. When mechanical forces are weak and heat supply small, intercepted snow stays where it first lodged. The question as to where the snow goes can be answered by saying that it does not go anywhere if mechanical and thermal energy does not move it.

5/ Muller, _op. cit._

EFFECTS OF MASS TRANSPORT ON SNOW COVER

Snow on the ground is the destination of some of the snow moving from tree crowns by the mechanical and thermal mass-transport processes that have been discussed here. This secondary transport of snow tends to increase the amount of snow on the ground in openings at the expense of the surrounding forest snow. It also brings a degree of metamorphosis to the snow on the ground, because although tree-borne it underwent alteration. The pits made in the snow cover by chunks of falling snow, the holes made by water drops, and the feathery crystals of vapor condensat represent successive stages of metamorphosis of the snow while it was aloft and successively greater effect when it joins the snow on the ground. Every kind of deposit of snow that moved from the trees alters the snow on the ground by making it more wet, compact and closer to its eventual dissolution.

Although much snow falls and blows from trees, not all of it does if the weather is cold. Cohesion increases as snow ages, making it more resistant to wind erosion. Partial melting of snow masses permits then to fall or slide off the branches at rates, according to calculations from experimental data, of 2 to 5 mm. per hour in water equivalent, if insolation is the major source of heat. During thaws, heat supply added by convection may cause snow to fall at double these rates.

If snow masses are stably supported and remain on the tree to melt, water moves by stemflow, though slowly, and by dripping, which is hard to assess from contradictory data. But from meteorological considerations this movement may be several mm. per day. Given heat and dry air, intercepted snow evaporates. But because we have no measurements of the vapor transport, we must again use meteorological criteria to approximate limiting rates and draw analogies to heat balances of snow-free conifer foliage and snow on the ground. These rates are lower than those cited for mass transport in solid and liquid form, because evaporation is a thermally expensive way to move water. Except during föhn, evaporation probably does not exceed 2 or 3 mm. per day.

The thermal mass-transfer processes have been summarized in order of increasing degree of transformation of the intercepted snow, and hence in order of increasing heat requirement. Evaporation is the process that moves the smallest mass for a given number of calories of heat. Reports of snow persisting in tree crowns for long periods in winter define climatic conditions principally low heat supply from radiation and advection, in which the mass-transport processes operate slowly or not at all.

In the present state of knowledge, even qualitative information on movement of intercepted snow can be made useful if accompanied by weather data. We hope that more field reports of mass transport, especially as liquid, will be published to serve as a basis for improving the assessments of transport and destination made here.

We will have to infer the destinations of snow moved by the mechanical and thermal processes pending controlled-environment experiments and micrometeorological studies. The products of intercepted snow in a drainage basin may increase soil moisture content, move into ground water, increase areal unevenness of snow on the ground, and decrease hydrologic storage in the basin by diffusion aloft. The processes that transform the intercepted snow into more fluid forms often help it bypass the snow cover on the ground: meltwater may move quickly into the soil, and vapor may escape the basin. While we can estimate limiting rates for these transport processes in a given climate, we cannot yet say, how the intercepted snow after a snowstorm will be divided as to destination. To the question of where does intercepted snow go, we can provide only qualitative answers.

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