SNOWMELT CHARACTERISTICS UNDER VARIOUS CONDITIONS

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ABSTRACT

Snowmelt rates vary in timing and magnitude depending on a number of factors. Snowmelt models attempt to simulate the snowmelt process based on meteorological factors, but very few actual measurements are available for validation purposes. This paper summarizes actual daily snowmelt data and compares the results to values reported in the literature.

INTRODUCTION

Snowmelt is affected by a number of factors including elevation, slope, aspect, exposure, snowpack depth, surface reflectance and climatic or meteorologic variables such as solar radiation, temperature, windspeed, vapor pressure, and precipitation. Snowmelt models attempt to account for these factors in various degrees from simple empirical relationships based on air temperature to detailed energy balance procedures. While detailed energy balance models should be superior in estimating snowmelt, there are rarely, if ever, adequate data sets available in practice to use these methods without making simplifying assumptions. Unfortunately, these simplifications usually reduce the models' ability to account for the various meteorologic factors that cause snowmelt to occur. Thus the models can produce estimates of snowmelt based on the input data available and the assumptions required, but these estimates may not relate to actual snowmelt in timing or rate. Since actual snowmelt data are very limited, it is seldom possible to compare model simulated melt rates with actual values. This paper is significant because it presents an analysis of snowmelt data under a variety of conditions (intermittent and general snow cover, accumulation zones associated with snow courses and snow pillows, and snow drifts) thus providing a range of snowmelt information that can be used to compare with snowmelt model simulations.

DESCRIPTION OF DATA AND METHODS OF ANALYSIS

Two types of data were used to determine the timing and rate of snowmelt from various snowpack conditions. The first analysis was made using USDA NRCS SNOTEL snow pillow data from 8 sites in the Boise River Basin of south central Idaho. These sites represent a range of elevation, aspect, exposure, and snowpack depths. The second analysis was made using data from 13 USDA ARS snowmelt collectors located on the Reynolds Creek Experimental Watershed, Upper Sheep Creek study site in southwestern Idaho. The collectors represent a range of snowpack conditions and aspects at approximately the same elevation. In a sense, neither sensor measures snowmelt directly. The snow pillow records changes in snow water equivalent (swe) of the snowpack above the snow pillow via a pressure transducer and includes losses due to sublimation and evaporation. The melt collectors measure the snowpack outflow at the bottom of the pack and may include snowmelt draining through the pack from previous melt events or rainfall flowing through the pack. Though these differences exist, it was assumed for this study that the processes other than snowmelt would normally be small on a daily basis and therefore the two data sets were analyzed as if they both represented snowmelt. While the rates of snowmelt thus developed may be slightly greater than actual snowmelt, the rates should more nearly represent absolute maximums. The period after January 1st of each year was considered as constituting the snowmelt season.

Data from the SNOTEL sites were obtained for the 14 year period (1982-1995) as daily values of snow water equivalent (Table 1). Typically depth of snow is not available at SNOTEL sites, however depth normally correlates well with swe. Therefore, the larger swe values indicate a greater snowpack depth. The rates of melt were determined from daily changes in snow water equivalent, and the timing of melt was determined by noting the date of the maximum melt rate or initiation of melt and the date of zero snow on the pillow. The melt collector data covered an 11 year period (1984-1994) (Table 2). The daily totals or daily melt rates were determined by accumulating the number of tips of the tipping bucket

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recording mechanism for each day. The timing was determined by noting the day of maximum melt, the date of initiation of melt, and the date of end of melt based on the cessation of tips and snowcover observations.

Table 1. Names, Elevations and Average Peak Snow Water Equivalent (swe) for SNOTEL sites in the Boise River Basin, Idaho for the period 1982-1995.

SITE IDENTIFICATION	ELEVATION (meters)	AVG. PEAK SWE (mm)
PRAIRIE	1463	114
GRAHAM G.S.	1734	386
MORES CK. SMT.	1859	908
JACKSON PEAK	2155	747
ATLANTA SMT.	2310	713
TRINITY MTN.	2368	992
DOLLARHIDE SMT.	2566	679
VIENNA MINE	2731	890

Table 2. Site Name, Elevation and Average Peak Snow Water Equivalent (swe) for Reynolds Creek Experimental Watershed, Idaho, Upper Sheep Creek site for the period 1984-1994.

SITE IDENTIFICATION	ELEVATION (meters)	AVG. PEAK SWE (mm)
SOUTH SLOPE	1865	225
GENERAL COVER	1875	342
N. SLOPE BELOW DRIFT	1902	465
N. SLOPE ABOVE DRIFT	1920	595
NORTH SLOPE DRIFT	1911	1520

RESULTS

Maximum snowmelt rates at the SNOTEL sites varied from 30 mm to 84 mm per day (Figure 1). Figure 2 shows that the timing of the snowmelt also varied considerably. The average length of the ablation period varied from 28 to 69 days (period from average day of peak accumulation to average day of melt-out), while the cessation of melt varied from day 98 to day 209. Snowpack snow water equivalent and elevation are noted to have a strong influence on the rate of snowmelt (Figure 1) and the timing and length of the snowmelt window (Figure 2). Typically, higher elevation sites tend to receive more precipitation, are cooler, have a longer accumulation period, and a later onset of melt, all of which tend to produce a deeper snowpack. The date of maximum snowmelt for each site was also influenced by snowpack depth and elevation (Figure 3) and tended to be at the latter part of the snowmelt season, often occurring after the average date of melt-out. The shallow, low elevation sites tended to melt out before snowmelt began at the deeper higher elevation sites. The high melt rates observed at high elevation sites usually occurred late in the season when there was more energy available for producing melt from the late-lying deep drifts.

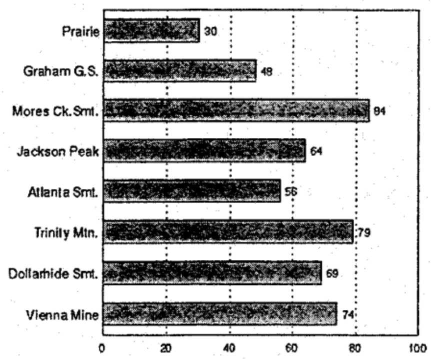

Figure 1. Maximum Daily Ablation from SNOTEL sites in the Boise River Basin, Idaho for the period 1982-1995. (mm/day)

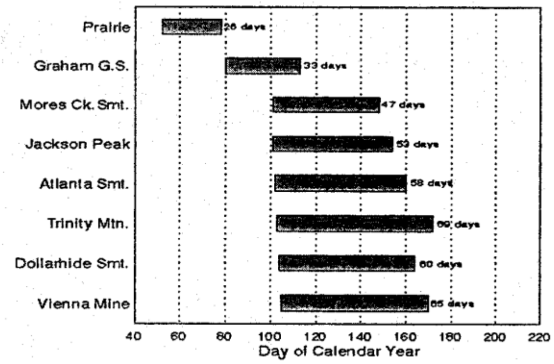

Figure 2. Average Length of Snowpack Ablation for SNOTEL sites in the Boise River Basin, Idaho for the period 1982-1995. (days)

Maximum snowmelt rates at the Upper Sheep Creek sites varied from 75 mm to 180 mm per day (Figure 4). The average duration of snowpack outflow only varied from 33 to 48 days at these sites (Figure 5). While the length of the snowpack outflow season varied from day 5 to day 167, the window of outflow or melt for each condition varied only from 87 to 106 days (Figure 6). In this case the melt rates and timing corresponded to snowpack depth and to aspect since all were at about the same elevation and all are in relatively open sites. The maximum rates at this site are associated with isolated late lying drifts that are subject not only to high radiant energy but also to considerable amounts of advected energy from adjoining bare ground during windy conditions.

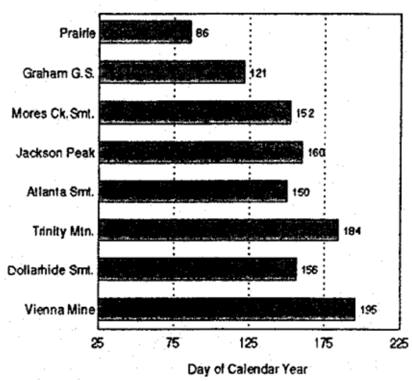

Figure 3. Day of Maximum Ablation for SNOTEL sites in the Boise River Basin, Idaho for the period 1982-1995. (days)

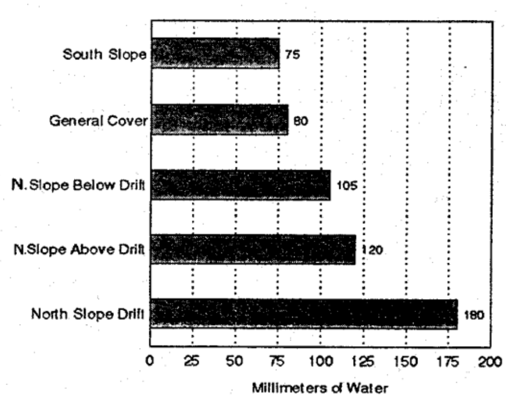

Figure 4. Maximum Daily "Snowpack Outflow" at the Reynolds Creek Experimental Watershed, Idaho, Upper Sheep Creek sites for the period 1984-1994. (mm/day)

In general maximum snowmelt rates were found to be about 30 to 75 mm per day for shallow snowpacks (114 to 225 mm swe) on south facing sites, about 50 to 80 mm per day for general snowcovered areas (330 to 850 mm swe) on a variety of exposures and aspects, and 100 to 180 mm per day for deeper snowpacks or north facing sites (465 to 1520 mm swe), with the highest rates tending to occur at the deepest sites.

For comparative purposes, melt rates from other studies were obtained from the literature. Erickson, et. al. (1978) noted that, at a prairie site, maximum 24 hour snowmelt amounts rarely exceed 55 mm of water equivalent. Bartos and Rechard (1974) reported rates of 60-65 mm per day from an isolated drift, while Tabler (1985) noted rates of up to 121 mm per day during the April to June 14th period and rates of up to 161 mm per day for the June 14 through July 3rd period from an isolated drift of nearly 5 m in depth in Wyoming. Matsuura, et. al (1996) measured melt rates of 190 to 214 mm per day at a study site in Japan from a 2 m deep snowpack. It was noted that a very strong advective component was present during this period due to high winds from the direction of nearby relatively warm ocean waters.

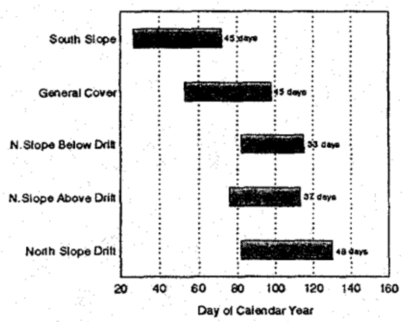

Figure 5. Average Duration of Snowpack Outflow at the Reynolds Creek Experimental Watershed, Idaho, Upper Sheep Creek site for the period 1984-1994. (days)

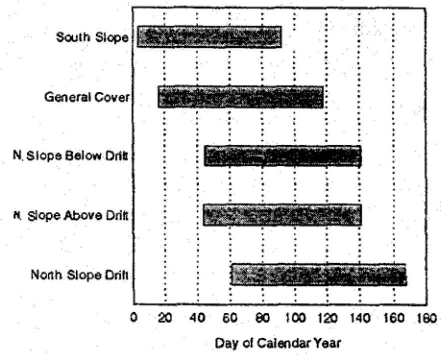

Figure 6. Time Window During Which Snowpack Outflow Occurred at the Reynolds Creek Experimental Watershed, Idaho, Upper Sheep Creek site for the period 1984-1994. (days)

CONCLUSIONS

The snowmelt rates presented in this paper should be of use as: 1) a check of upper limits for snowmelt model simulations; and 2) for information concerning the timing and rate of melt under various conditions for those interested in the climatic characteristics of snowmelt processes. The maximum snowmelt rates reported in the literature are of essentially the same magnitude as those observed in this study. However, this study provides a method of categorizing the melt rate values and timing according to snowpack depth or snow water equivalent.

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