Wind–Snow Relations at Marmot Creek, Alberta

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Wind patterns are crucial factors to be considered in the design of artificial clearings in the forest to trap and retain snow. Winds at Marmot Creek during snowfall are predominantly southeasterly but are quite light; over 80% of the snow falls with winds less than 4.5 m/s. Maximum winds occur between snowfalls, and favor the southwest to northwest quadrant. The average maximum hourly wind per month is less than 7 m/s in the lower reaches but increases with elevation to 16 m/s at treeline.


Le comportement du vent est un facteur essentiel lors de la planification de clairières artificielles qui serviront en forêt à amonceler la neige. Lors des chutes de neige, les vents à Marmot Creek soufflent surtout du sud-est mais sont très légers; plus de 80% de la nivosité se produit lorsque la brise n'atteint pas 4.5 m/s. Les vents maximaux soufflent entre les tempêtes de neige, viennent surtout du sud-ouest ou du nord-ouest. La vitesse horaire maximale moyenne pour mois fait moins de 7 m/s à faible altitude, puis elle augmente progressivement avec l'altitude à 16 m/s à la limite des arbres.

Introduction

The study of snow accumulation patterns with respect to vegetation types and density, and forest harvesting practices is one of the most promising avenues of research in watershed management. To obtain optimum use of snowmelt water, a delay in the time of snowmelt is required, which in turn requires maximum snow accumulation in small areas where it is shaded from solar radiation. Wind data on both speed and direction, both during periods of snowfall and between falls, are needed for an understanding of snow accumulation patterns and for the design of artificial snow-trap clearings. Court (1957) has shown such data on wind directions for a 3 month period at Castle Creek, California. Small openings in the forest have been found to act as efficient snow-traps because of the lower roughness factor. The size and orientation of the most efficient traps are partially dependent on wind speed and direction, respectively, during snowfall. Large clear-cut strips are not efficient because of exposure to the sun and scouring of the snow by strong winds. A knowledge of the strength and direction of high winds during non-snowfall periods will assist the design of long, narrow openings with minimal risk of scouring. This study was therefore prepared to obtain these wind data and is part of the Atmospheric Environment Service’s contribution to the Alberta Watershed Research Program at Marmot Creek. Further studies are required to relate these data to tree height, basin topography, and orientation to determine optimum clearing size and length to width ratios.

Area Description and Instrumentation

Marmot Creek (Fig. 1) is a rugged, mountainous experimental watershed of 9.4 km² in the Kananaskis Valley about 80 km west of Calgary and has been described by Jeffrey (1965). The general aspect is easterly but individual slopes may face any direction from north through east to southwest. Elevations range from 1583 to 2800 m MSL, with an average slope of 39% causing numerous access problems. The lower reaches to about 1770 m are covered with a dense stand of lodgepole pine, then mature spruce up to 30 m tall extend to treeline at 2130–2285 m (Kirby and Ogilvie 1969). In the alpine area, shrubs and grasses give way to bare rock and talus.

Wind observations have been taken since July 1967 at Twin 12 and since July 1968 at Twin 1 (Fig. 2) using MSC type 45B anemovanes recording speed and direction continuously on Esterline–Angus strip charts. The Twin 12 instrument is on top of a 45 m tower at 1800 m MSL and is approximately 15 m above the tallest trees. The Twin 1 anemovane is mounted on a 9 m mast at 2285 m MSL on the ridge between Middle and Twin Sub-basins (Fig. 3). It is just above treeline but appears fairly representative of the upper levels of the forest. Wind observations were also taken from 1965 to 1967 on a 9 m mast at Con 4 at 1675 m MSL and from 1964 to 1967 on a 6 m mast at 2440 m on the ridge between Cabin and Twin Sub-basins (A, Fig. 3). Numerous breaks in the record at site A reduce its value for this study. Also

Fig. 1. Aerial view of Marmot Creek looking westward to the continental divide.

Fig. 2. Site Twin 1, elevation 2285 m MSL.
it is well above treeline so not representative of the forested area.

Continuous snowfall data were provided by a Leupold-Stevens Q12M weighing type gauge at Con 5 at 1770 m, about 200 m east of Twin 12 and 2.3 km east of Twin 1. The time and amount of major falls were obtained more precisely than minor falls. Ten storage gauges in the basin measured the areal variation in snowfall (Storr 1967).

Wind Patterns During Snowfall

Within the limits of accuracy imposed by the instrumentation of the basin, the Con 5 data are representative of the time of snowfall in the basin, at least for major events, and can be used to determine wind patterns in speed and direction during snowfall. Con 5 snowfall, however, is not representative of the amount of snow which falls in the basin. Golding (1968) has found a linear relationship between snowpack and elevation at Marmot Creek. The relationship between the basin average for the season’s total snowfall as determined by Thiessen polygons from the storage gauge data, and Con 5 is shown in Fig. 4. It is likely that a similar relationship exists for most snowfall periods, so relationships between

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**FIG. 3.** Site locations at Marmot Creek.

**FIG. 4.** Basin mean snowfall versus Con 5 snowfall.
Fig. 5. Percentage of total snowfall at Con 5 by wind direction at Twin 12.

Fig. 6. Percentage of total snowfall at Con 5 by wind direction at Twin 1.

Con 5 snowfall and wind should be valid for basin snowfall.

A cross-tabulation of hourly snowfall amounts at Con 5 against hourly mean wind velocity at Twin 12 for the period September 1967 to October 1970, and at Twin 1 from September 1968 to October 1970, formed the basis for Figs. 5 and 6, the sector roses of percentage of total snowfall at Con 5 by wind directions at the two sites. There is a large preponderance of southeast winds during snowfall at both sites. At Twin 12, the wind is southeast or northwest for 42% of the Con 5 snowfall, for 45% at Twin 1. Wind roses of percentage of hours of wind and miles of wind during snowfall were also prepared but are not presented here. They showed very similar patterns to those in Figs. 5 and 6. Figure 7 is the envelope curve for Con 5 snowfall and wind speeds at Twin 12 and Twin 1. Speeds were very low at both sites; 80% of the snow fell with winds less than 2.2 m/s at Twin 12 and 4 m/s at Twin 1; winds were calm at Twin 12 for 12% of the snowfall, for 3% at Twin 1.

Strong Wind Patterns

The frequency, strength, and direction of strong winds are important factors in the study of redistribution of snow after it has fallen, and hence in the design of artificial clearings in the forest. The duration of strong winds is also important, but its relative importance versus strength is a complex problem depending on such other factors as the degree of consolidation of the snowpack and its water content, and the height and density of the vegetation. Because wind speeds during snowfall have been found to be light, it follows that the maximum speed each month occurred between snowfalls. The results of a frequency
analysis of maximum hourly and maximum daily mean speeds for 32 months in the snow-cover season at Twin 12, 22 months at Twin 1, 20 months at Con 4, and 12 months at A are shown in Fig. 8. It must be stressed that the periods of record are not simultaneous, but they are the only data available. As noted earlier, the data from Con 4 and A overlap, as do Twin 1 and Twin 12. As pointed out by Bruce (1959) and others, the statistical significance of 'return periods' should be noted. A 20-month wind (either hourly or daily) is one which will be equalled or exceeded on the average once in 20 months. Its reliability is a direct function of the length of record. An attempt at a similar analysis for maximum 4 min and 8 min winds was inconclusive due to imprecise recording methods. The average monthly maximum 4 min and 8 min winds for the above periods of record are 15.6 and 13.4 m/s at Twin 12, and 27 and 24 m/s at Twin 1.

A general increase with elevation in the return period values of maximum hourly wind
speeds is illustrated in Fig. 9. The increase from Con 4 to Twin 12 is quite small, but quite marked between Twin 12 and Twin 1, and very pronounced between Twin 1 and A. Once again the nonsimultaneous period of record must be stressed, so the relationships in Fig. 9 are more suggestive than conclusive evidence. It is very tempting to indicate a linear relationship between maximum wind speeds and elevation in the forested zone, and an exponential relationship in the alpine area, but a longer period of simultaneous record with more uniform exposure of sensors and more adequate sampling of wind and elevation is needed to confirm or reject this hypothesis. No values of the critical speed for redistributing snow are available for conditions at Marmot Creek. However the mean speed of the monthly maxima at Twin 12 (8.1 m/s with a standard deviation of 1.7) is only about half that at Twin 1 (16.0 with a standard deviation of 3.0), so the problem of scouring in large clearings increases with elevation.

The favored direction of the maximum hourly winds in each month at Twin 12 and Twin 1 is shown in Figs. 10 and 11. Over 50% of the monthly maxima at Twin 12 is from the southwest, almost 25% from northwest, and 15% from the west. At Twin 1, 43% of the monthly maxima is from the west, almost 40% from northwest, and 17% from southwest.

**Conclusions**

As mentioned earlier, wind patterns are only one factor to be considered in the design
of artificial clearings to optimize use of snow-water. The results of this study indicate that:

1. Southeast and northwest winds predominate during snowfall at all levels sampled in the forested zone at Marmot Creek, so clearings should be oriented southwest to northeast.

2. Although wind speeds during snowfall are generally light, there is approximately a 100% increase between the lower levels and tree-line in the basin.

3. Maximum winds between snowfalls in the lower levels favor southwest, but scouring of the snowpack is unlikely because of their relative weakness.

4. In the upper levels, winds between snowfalls are frequently strong enough to redistribute the snow in exposed areas. Clearing size should therefore decrease with elevation.

Figure 1, the aerial view of Marmot Creek, is from the files of Canadian Forestry Service, Environment Canada, Edmonton, Alberta. Figure 2, the view at Twin 1, is by courtesy of Mr. Z. Fisera, Canadian Forestry Service, Kananaskis Forest Experimental Station, Seebe, Alberta.


