SURFACE WIND STRUCTURE IN FOREST CLEARINGS DURING A CHINOOK [1]

By

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Introduction

Chinook winds in Alberta have a reputation for being "snow eaters". Where their full force is felt, evaporation rates of 12 mm per day or more have been calculated. The snow under a forest canopy is protected from the full force of chinooks because of the physical retardation of surface wind speeds by the leaves and branches of this overstory.

One question relevant to water production from forested areas which are subject to chinook conditions is "how large a clearing can one create before the protective effects of the surrounding canopy become negligible at the surface of the clearing?" Bergen (1976) indicates that surface winds across the 1H dimension of a 1 by 5-tree height clearcut strip were virtually unaltered from those existing before the clearing was created, that is they were still very low. Brown (1972) reports that wind speed in approximately 3-tree height (3H) wide clearcut strips was 45 percent of that above the canopy. Wind speeds in the lee of shelter belt strips are approximately 50 percent at 10H and 80 percent at 20H (Sturrock, 1972). These data hint at the range of variation one might expect.

The manager of a forest in a chinook wind area, whose task it is to choose from among alternative clearcut sizes and arrangements that would accumulate and favour maximum retention of snow in the face of these winds, is confronted with a complex physical and economic problem. The studies cited above indicate that he should opt for very small clearcuts to provide significant protection from the wind. The logger favours much larger clearcuts as they reduce his operating cost. The usual solution is some compromise size of clearcut that, although good economically, may be of little or no value in solving the physical problem.

Methods

The purpose of this investigation was to obtain an indication of the degree of protection to the snow surface that would be afforded in various sizes of clearcuts from high wind speeds (20 to 45 m/sec). The opportunity for evaluating wind reduction in a variety of clearcut sizes existed at a special snow research site in a very uniform 20 m tall, 100 year old lodgepole pine stand in South Central Alberta near Sundre, Fig. 1. At this site, 10 replications of circular clearings from 1/4 to 6H in diameter were clearfelled from 1969 to 1974. The details of this research area and the snow accumulation and ablation rates in these clearings were reported by Golding and Swanson (1978). In January 1979, 8 climatic stations with 3-cup anemometers at approximately 2 m height and 4 stations with 3-dimensional wind vector propellor anemometers, also at 2 m, were established in the centre of three each of the 1, 2, 4, and 6H circular clearings. A single, i.e. not replicated, 3-cup station was established at 2 m height in the centre of a 20 by 20H square clearcut, and a second at 10 m above the continuous forest canopy. Prior to this study, wind speeds had been ascertained to be uniform throughout this 25 km^2 research site by analysis of variance of measurements of above-canopy wind speed at 4 randomly located 30 m tall towers, made during the period 1972 to 1978.

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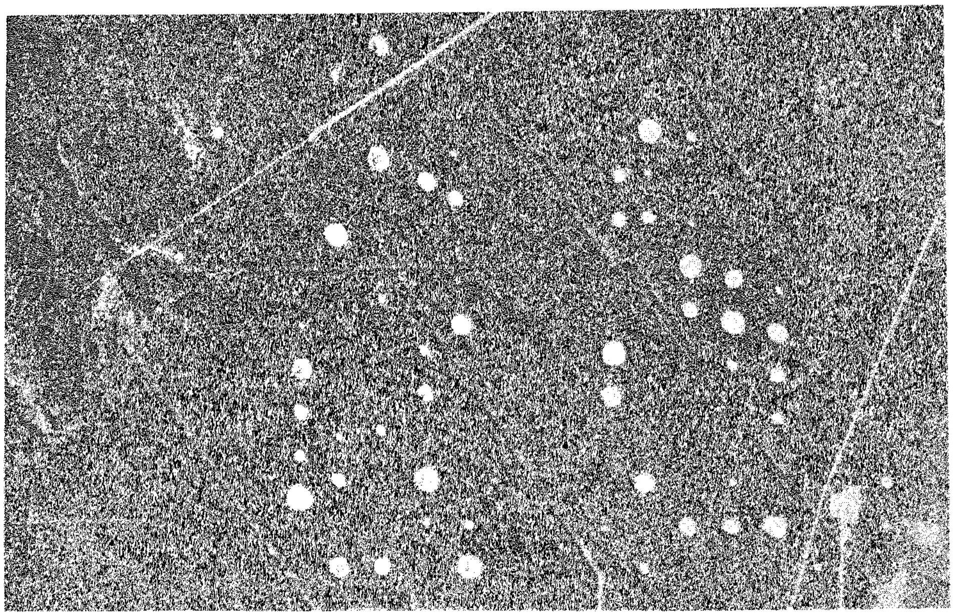

Figure 1. Approximately 90 circular clearcuts in 20 m tall lodgepole pine near Sundre, Alberta. The largest circular clearing is 120 m diameter. Wind fetch to nearest topographic obstacle is approximately 11 km. Linear clearings are geophysical exploration trails.

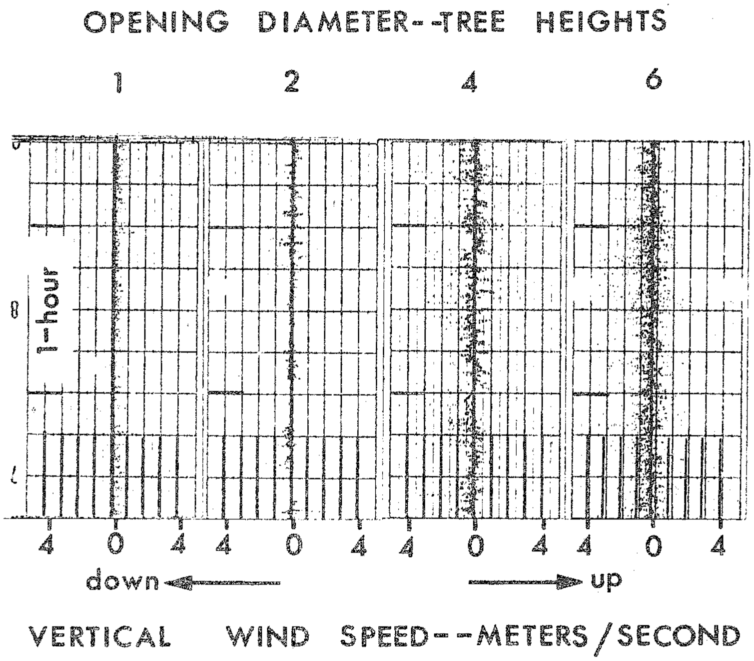

Figure 2. Vertical wind speed recorder chart traces from 1, 2, 4 and 6 tree height diameter clearings. Note that true zero, denoted by the heavy line through the data, does not necessarily correspond with the recorder chart line.

Results

One chinook wind period with daily mean wind speeds above canopy ranging from 4 to 12 m/sec occured from April 5 to 8, 1979. The average daily data for the 3-cup stations in each opening size is given in Table 1; a 1-hour sample of the vertical wind speed on 7 April from the vector anemometer sets in Fig. 2.

Table 1. Daily mean wind speed, m/sec, in circular clearings at James River snow study site, Alberta, April 5-8, 1979. Height of 3-cup anemometers 2 m in clearings. 10 m above tree canopy.

			opening diameter, tree heights				
Date	0	1	2	4	6	20	Above Canopy
5	0.04	0.09	0.27	0.56	0.60	1.88	4.74
6	0.27	0.13	0.31	0.60	0.80	3.13	3.89
7	0.18	0.18	0.31	0.38	0.51	3.08	11.44
8	0.36	0.18	0.34	0.51	0.72	5.63	8.40
Average	0.21	0.15	0.31	0.51	0.66	3.43	7.12

Horizontal wind speed is significantly less than above-canopy in the centre of clearings 1 to 6H in diameter. Speeds are always low in these openings regardless of the magnitude of the above-canopy wind speed. Eqn. (1), a normalized 2nd degree fitting of the data, may be helpful to those who want to quantify the wind speed reduction that a particular clearing size between 1 and 20 to 30H affected compared to that above the canopy or free of edge influence.

$$\frac{U_{\text{opening}}}{U_{\text{above canopy}}} = 0.0214 + 0.0067H + 0.00084H^2 \qquad (1)$$

Where H = clearcut dimensions in tree heights
U = horizontal wind speed

Wind speed in the 20H clearcut closely follows that above canopy. A logarithmic extrapolation of the mean daily wind speed at 10 m above the canopy down to 2 m approximates that found in this clearcut. This suggests that the edges of this 20H clearcut have little influence on wind speed at the centre.

Vertical wind motion is much reduced in 1 and 2H clearings compared to that in 4 or 6H. These data were impossible to quantify into net upward or downward motion from the recorder traces, Fig. 2. However the average amplitude variation appears to be about ± 0.1 m/sec in the 1 and 2H versus ± 0.4 m/sec in the 4 and 6H clearings. No vertical data were obtained in the 20H clearing nor above the canopy.

Discussion

Evaporation from snow is generally small under forest canopy. West (1962) reports net evaporation rates of 0.5 mm/day under forest canopy and in clearcuts up to 2H diameter in California. Evaporation rates increased to 0.83 mm/day in clearings greater than 4H in diameter. In all sizes of clearings, evaporation was proportional to near-surface (Z=40 cm) wind speeds. Bergen and Swanson (1964) found similarly low evaporation rates for a sheltered location in the much colder and 'dryer' continental snow conditions in Colorado. Hutchinson (1966) working in a less sheltered location (centre of a 10H opening) found evaporation rates of 0.91 mm/day, i.e., almost double

West's sheltered rates. Doty and Johnston (1969) found 8-hour evaporation rates in an open area among an aspen stand to be 0.28 mm, under the aspen 0.20 mm, and under dense Douglas fir true fir canopy 0.13 mm. These rates are apparently from wind-sheltered locations.

Williams (1958) reports evaporation from snow ranging from 0.029 to 1.64 mm/day at an exposed site near Ottawa. Upon examination of his data, one can attribute about 70 percent of the evaporation to wind speed. This is fairly well in line with Ross and Picot (1975) who found that the heat transfer coefficient from air to snow was approximately proportional to wind speed. Certainly if snow is carried by wind it is subject to severe sublimation loss if transported any sizeable distance (300 to 1200 m) (Tabler, 1973). Storr (1968) indicates that evaporation from snow under chinook wind conditions at the Marmot Experimental Watershed in Alberta, could reach 12.5 mm/day. Golding (1978) using data taken near Marmot during chinook wind periods, calculated evaporation losses from snow fully exposed to the wind at 1.2 mm/day in 1976 and 2.0 mm/day in 1976.

The importance of local air motion in heat and vapour exchange is recognized but poorly understood in the 3-dimensional situations that interspersed forest clearing and treed areas present. Male and Granger (1978) indicate that local and large scale advection are significant but difficult to evaluate processes affecting local snowmelt and evaporation. They indicate that the sensible heat fluxes from adjacent dark coloured areas, such as bare soil, patches of trees, etc., can produce nighttime evaporation because of a flux of incoming heat greater than the radiation loss. There is every reason to believe that the larger scale advection of heat occuring during chinook winds would have similar effects.

It is evident from these studies that snow evaporation can vary widely depending primarily upon wind conditions at the snow surface. Uncut forest and small clearings have similar and low evaporation rates. Clearings greater than a minimum dimension of about 4H can show widely variable evaporation rates dependent upon surface wind speeds.

The results reported herein indicate that the surface of 1 to 6H clearings do not receive the full force of the above-canopy winds. Neither does there appear to be very much vertical exchange with the above-canopy air mass in the 1 and 2H clearings. Vertical motion certainly increases in 4H and larger clearings, but without some indication that outward motion predominates, one cannot assume higher water vapour flux from these than from those smaller.

The low amplitude of vertical motion in the 1 and 2H clearings suggests that a stagnant layer of air may occur in these clearings that has little exchange with the above-canopy layers. If this is so, then these tiny clearings offer potential to greatly reduce evaporative loss from snow, soil, or low vegetation surfaces compared to that of either high forest or large clearcuts. The evaporative surfaces of such small clearings would be effectively 'cut off' from the larger but still local climatic circulation that one ordinarily measures and from which he calculates potential or actual evaporation.

Conclusions

Horizontal wind speeds at 2 m in the centre of 1 to 6 tree height diameter circular clearings in 20 m tall lodgepole pine forest was reduced to about 1/20 of that found 10 m above the canopy, while that in the centre of a 20 tree height square clearing was only marginally less. Since evaporation is affected by advective energy transfer, these data imply smaller evaporation rates from the snow, soil or low vegetation surfaces in 1 to 6H clearings than from those 20H and larger. Vertical air motion is greater in 4 and 6H than in 1 and 2H clearings. The quantitative significance of such vertical motion to potential or actual evaporative loss could not be determined from the data of this study.

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