SNOW REDISTRIBUTION FROM FETCH TO STARTING ZONE[1]

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Abstract. The measurement of snow redistribution from fetch to starting zone was initiated to provide a relationship, due to wind, between snow loss in the fetch, avalanche starting zone snow accumulations and avalanche occurrences. Greatest starting zone accumulations occur when specific topographic features, precipitation patterns, wind direction and wind speeds are combined. However, only a small percentage of the snow available for transport upwind reaches the avalanche starting zone.

INTRODUCTION

The study area, Snowmass Ski Area, Colorado, combines a high elevation continental snow climate with topographic features which include a large ratio of fetch area (2,613,000 m^2) to avalanche starting zones (122,359 m^2) above timberline (Figure 1). Peak wind speeds of 36 m/s were recorded and a daily average peak wind speed of 14.6 m/s, flowing across the fetch at a prevailing wind direction of 240^o with fetch extending as much as 2,174 m upwind combine to create the potential for redistribution of large amounts of snow into avalanche starting zones.

PROCEDURES

During the winter of 1983-84, daily field observations were taken from a study site located on a protected north exposure at 3230 m. Measured parameters include total snow depth, new snow from a 24 hour storm board, new snow water equivalent and snow temperature 20 cm below the snow/air interface. In addition, meteorological conditions were recorded every three hours in the fetch above timberline at 3,600 m and included air temperature, wind speed and wind direction (maximum, minimum and average values). Humidity was recorded on a barograph at 2743 m.

During or after each significant weather event, fetch and starting zone conditions were observed. Snow depths were monitored with bamboo poles marked with either 10 cm or 30 cm alternating red and black increments to allow for safe observation with field glasses at distances of approximately 50 m.

Five markers within the fetch were located at fixed distances along a transect parallel to the prevailing wind direction. Seven markers, including one permanent tubular steel stake, were

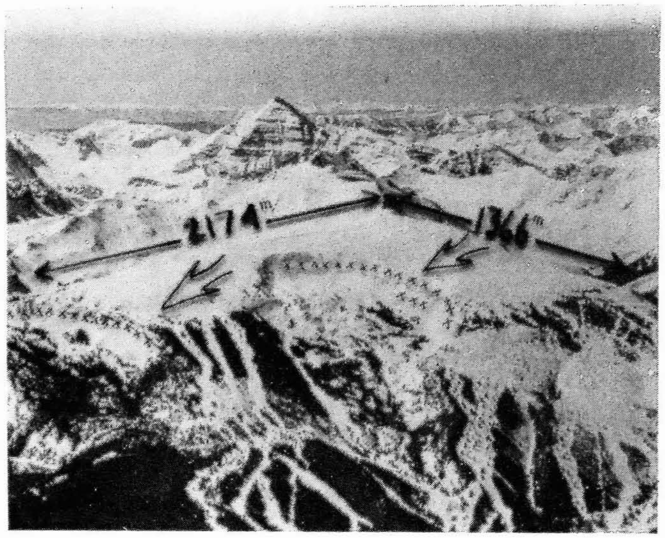

Figure 1. Fetch and accompanying starting zone of Snowmass Ski Area from the north looking south into the fetch. XXX indicate starting zones in the study areas. Arrows indicate two year mean wind direction of 245^o.

located within several avalanche starting zones chosen for their distinct topographic features. The markers were placed at sites that experience the greatest accumulation of wind deposited snow, as indicated by avalanche control and weather records. Hasty snowpits were dug within the fetch area to examine stratigraphy and density within the uppermost 50 cm of the snow cover. When practical and safe, hasty snowpits were dug in starting zone areas to obtain new snow depth and density. Actual losses or gains of snow in the fetch and starting zones were then related to meteorological and field observations.

An artificial catchment was constructed in the fetch area at 3657 m. A snow vehicle was used to create the catchment, which resembled a gradual rounded crest. The catchment, 10 m in width, 20 m in length and 3 m in height was positioned

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length wise, perpendicular to the prevailing wind direction. New snow accumulation and density were observed.

FINDINGS

The following combined conditions contributed to a snow water equivalent accumulation in a starting zone of 246 mm of water equivalent with 590 m of fetch upwind: peak wind speeds of approximately 18-24 m/s, precipitation of approximately 35 mm of water equivalent or greater over the storm period, wind direction within 20^{o} of perpendicular to the starting zone, and a convex transition (gradual rounded crest) from fetch to starting zone.

Although gains in the starting zone were recorded with wind speeds greater than 24 m/s, the total seasonal accumulation in the starting zone represents a small percentage of the total snow available for transport out of the fetch. For example, on December 22 and 23, 1983, wind speeds of 34 m/s (wind direction of 265^{o}) were recorded. The snow water equivalent removed from the fetch was 69.8 mm x 2174 m = 151,745 mm (that is the contributing area of fetch one m wide by 2174 m long, upwind from the avalanche starting zone). The area of deposition with an equal width of the fetch (1 m) extending 100 m through the starting zone gained 65.5 mm x 100 = 6550 mm of snow water equivalent, less than 5% of the total snow transported out of the fetch.

SUMMARY

The major preliminary findings are:

1. Wind direction with respect to starting zone orientation is critical; 20^{o} either way from perpendicular causes accumulation to diminish significantly.

2. Precipitation at the time of transport greatly increases starting zone snow accumulations.

3. Starting zone snow accumulation appears to be a function of windspeed:

   A. At 0-12 m/s, any blowing snow had minimal effects on starting zone accumulations.

   B. At 12 - 18 m/s, starting zone accumulations depend on precipitation and fetch conditions (how long the surface snow has remained in the fetch due to static weather trends, crust formation at the snow/air interface and air temperatures.

   C. At 18 - 24 m/s, greatest starting zone accumulations occur if precipitation is present (56% of all avalanches recorded during the 1983-84 winter season occurred immediately adjacent to the fetch at ridgecrest above timberline. Of that total 68% were influenced by wind speeds of 18 - 24 m/s, with blowing snow and precipitation present).

   D. At 24 - 36 m/s, starting zone accumulations decrease rapidly, regardless of precipitation (as wind speeds increased above 24 m/s avalanche frequency adjacent to the fetch at ridge crest above timberline diminished from the seasonal 56% to 30%, with the remaining 70% occurring below timberline).

4. As fetch size increases, accumulation ratios decrease (that is the ratio of wind-deposited snow in the starting zone to that amount of snow assumed to be available for transport in the fetch).

5. With respect to avalanche starting zone topographic features, the gradual rounded crest from fetch to starting zone was the most efficient catchment (winter total = 1383 mm water equivalent). Next efficient catchment was an immediate transition from fetch to starting zone angle of 38^{o} (winter total = 1241 mm water equivalent), with the least efficient catchment being a transition from fetch, 25 vertical meters of cliff to a starting zone angle of 36^{o} (winter total = 871 mm water equivalent).

IMPLICATIONS AND RECOMMENDATIONS

Expansion of this program during the 1984-85 winter season will include a more thorough measurement of new snow accumulations by transecting the avalanche starting zones with bamboo markers. Observation of snow density and stratigraphy in the fetch and starting zones will increase.

Artificial catchments constructed during the 1983-84 winter season will not be constructed again due to a deficiency of useful information for the control program.

It is the view of the author that the majority of snow deposited in the fetch over the entire winter season either is never transported out of the fetch, sublimates during transport (R.A. Schmidt, USFS Rocky Mountain Station, 1972), or is transported beyond starting zones to the more dense forest cover of lower elevations.