PROBABILITY ANALYSIS OF AVALANCHE FORECASTING VARIABLES

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EXTENDED ABSTRACT

Introduction

Perla (1970) provided a simple probability analysis of individual factors thought to be important in avalanche hazard evaluations using 20 years of storm data from Alta, Utah. Since then, no similar analysis has been presented for comparison of individual factors from different mountain ranges or climate zones. In this study, 11 years of snow, avalanche and weather records using twice-daily measurements relevant to prediction of the avalanche hazard for the Kootenay Pass Highway in B.C. are analyzed using a method which differs slightly from that applied in the Alta study. Perla used only storm data, whereas we used data gathered from both avalanche and non-avalanche time periods (artificial and natural avalanches were included). Although our time record is shorter, our data base is much larger: approximately 3300 sets of twice-daily observations. These differences affect details but the final results are very similar.

Method

Our data were collected by making twice-daily standard observations according to Canadian standards (NRCC, 1989). Variable retention was based upon two factors: (i) those factors which were shown to be significant in a discriminant analysis of avalanche/non-avalanche time periods and (ii) some variables were retained in order to compare with the original analysis of Perla (1970) and Atwater's (1954) prescription of the contributory factors in hazard forecasting. We categorized the significant variables (four or more categories usually increasing in value) by constructing scatter plots of each variable as a function of the avalanche activity (defined as the sum of sizes on the Canadian scale. Refer to Perla (1970) and McClung and Tweedy [1993(a)] for more details. This enabled definition of the avalanche probability for each category of each variable. Three levels of conditional avalanche probability were calculated: (i) the fraction of times for which avalanching occurred in each variable category; (ii) same as (i) except the sum of the avalanche sizes was greater than or equal to 3; (iii) same as (i),(ii) except the sum of sizes greater than or equal to 10 was used.

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Variable Classes

We classed variables in our study (11 were retained) as primary and secondary depending on the shape of the probability plots as defined by Perla (1970): avalanche probability on the ordinate versus (catgorized) values of the variable on the abscissa. Primary variables were those in which the shape of the probability plot showed monotonic increase with increasing value of the categorized variable. Secondary variables were those which showed oscillatory behaviour on the probability plot. In our study, primary variables included: snow-fall rate, weight and water equivalent of new snow, total storm snow and new snow depth. Secondary variables included: wind speed and direction, and new snow density. Precipitation type showed only a strong, positive trend with freezing rain. Surface moisture condition showed alsmost no trend except for conditions with a very wet surface. It is noteable that when wind speed increased from light to moderate (NRCC, 1989) a significant increase in avalanche probability was indicated but otherwise no strong trends were evident. The correlation of avalanche probability with wind direction was weak but observable: wind directions from the south and west sector showing the highest probabilities. For wind direction, we believe the correlation is due to the fact that this sector is the prevailing storm wind direction for Kootenay Pass rather than something more fundamental.

Comparison With Perla's Results

Perla's (1970) study differed from ours with respect to data collection methods and variables analyzed. However, essentially the same size classification was used for representing the avalanche activity [NRCC, 1989; McClung and Tweedy, 1993(a)]. In addition, the climate type for Alta and Kootenay Pass [McClung and Tweedy, 1993(a)] is similar: transitional (in between maritime and continental). Perla's results showed similar results: precipitation rate (maximum and average), total storm snow and new snow depth were primary variables; wind speed and direction were secondary variables. In Perla's study, however, the variables defined as primary and secondary depend more on the avalanche activity than for our study. For probabilities calculated with the sum of the sizes greater than or equal to ten for a storm, all the factors except wind speed and direction are primary variables in Perla's analysis. In contrast, our study shows very little sensitivity for individual variables as a function of avalanche activity.

Analysis Method

Studies of this nature can help to confirm what forecasters suspect about the importance of variables measured in forecasting. However, it should be kept in mind that the analysis is done almost exclusively from the view of single variable representation. In reality, snow and weather variables <u>combine</u> to produce avalanching. Therefore, variables which <u>appear</u> to be important in a single variable approach may be much less significant (or not significant at all) in a multi-variate approach. In an operational sense, multi-variate analysis must take presidence; McClung and Tweedy [1993(b)] provide the companion multi-variate approach for Kootenay Pass.

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