Geophysical Research Abstracts, Vol. 8, 09663, 2006
SRef-ID:

Spatial extrapolation of slab stability indices for snow avalanche forecasting

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In the Columbia Mountains of western Canada, some avalanche forecasting programs measure slab stability indices in study plots near tree-line and often find these indices to be indicative of slab avalanching many kilometers from the study plot. Research in the same mountain range has confirmed the correlation between the indices and avalanche occurrence. Due to spatial variability and scale issues, the explanation for the correlation between the indices, which are measured over a small area, and avalanching many kilometers away has been unclear. Explanations are provided in terms of the strengthening response of weak layers to increases in load (snowfall) and the commonly used measure of forecasting success.

The stability indices for natural (spontaneous) avalanches are ratios of shear strength of a weak snowpack layer to the shear stress on the weak layer applied by the overlying slab. The denominator of these ratios is proportional to overburden pressure, referred to as load. At five study plots, nine time series of shear strength and load measurements of buried surface hoar layers extending over 22 to 49 days are analyzed. Daily rates of loading at the study sites and during the time series range from 20 to 120 Pa/d. Rates of change of shear strength range from 26 to 195 kPa/d. The correlation between the average loading rates and the average rate of strengthening ($r = 0.97$) shows that the ratio of shear strength to load varies much less over terrain than the variations in shear strength and load. Consequently, different sites exhibit concurrent decreases in the strength-load ratio during snowfall and concurrent increases in the ratio after snowfall. The response of shear strength to load is explained in terms of densification and pressure sintering between grains.

Typically, an extrapolated stability index is considered successful if one or more of the surrounding start zones releases an avalanche in a time period of a day or less when the

index has a low value, or if none of the surrounding start zones release an avalanche in a time period when the index has a high value. Thus, a stability index obtained in a study plot can exhibit a high success score if only some of the surrounding start zones exhibit short term variations in the strength-load ratio resulting from snowpack stratigraphy (including a weak layer) that is similar to the study plot.

Extrapolated stability indices are used in the Columbia Mountains but rarely in other ranges. This is likely due to the limited effect of wind on avalanche formation in the Columbia Mountains. During occasional storms with high winds, avalanche forecasters in this range report extrapolated stability indices are not useful indicators of avalanching. Consequently, such indices are likely less useful for avalanche forecasting in mountain ranges with more wind.