Research to improve forecasting for natural deep slab avalanches

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Introduction

Deep slab avalanches are a major concern in mountainous terrain due to their destructive power and often unpredictable release. A magnitude of factors must exist for a large deep slab avalanche to form, including a weak internal layer or interface in the snowpack, deep snow that overlies the weakness, a natural trigger that ultimately causes the weak layer to fail, and a snowpack and terrain that allows the failure to propagate over a large area. They are often found in alpine and subalpine terrain, usually on an aspect prone to windblown snow deposition or high solar radiation, but some hard to forecast ones don't follow this pattern. The persistent weaknesses that release deep slab avalanches are formed well in advance of much of the overlying slab and continually evolve with time due to temperature, vapour pressure, and mass loading variations. The weakness is often for a layer of faceted crystals above or below a crust or buried surface hoar.

The definition of a deep slab avalanche varies. For the purpose of this research, it is defined as an avalanche with an average crown of at least 80 cm and one that failed on a weak layer at least two weeks old. This definition should eliminate avalanches from recent storm snow.

Forecasting deep slab avalanches is difficult because of the many variables involved, including seasonal weather, recent weather prior to failure, terrain, and slab load and strength characteristics. Previous research has typically relied on database studies, as most deep slab avalanches are not analyzed in great detail using techniques such as fracture line profiles and snowpack tests to assess the properties of the slab and weak layer. The lack of data available on such avalanches produces a difficult task in determining correlations to improve our forecasting abilities.

We are trying to determining which snowpack properties in release zones are associated with deep slab avalanches and the importance of spatial variability. The importance of preceding weather is also tied into the analysis to determine correlations between weather and the snowpack.

Field Data Collection

Accessing deep slab avalanche locations soon after they release is the primary method of obtaining data to provide insight into the cause of failure. Naturally, this limits the amount of locations due to accessibility and safety concerns. Terrain characteristics, measurements along the crown, and weather data are obtained from safely accessible avalanche sites to determine correlations between events.

Deep slab avalanche crowns in the Lizard Range, British Columbia

Travel to the start zone provides important information such as avalanche size, aspect, terrain characteristics, and variability of the crown thickness. Once at the avalanche, a snow pit is dug at a representative location of the overall crown. The pit is used to identify the failure layer, analyze the layers directly above and below, conduct density measurements of the snow above the failure layer, and perform multiple deep tap tests (DTs) and propagation saw tests (PSTs). If time and safe travel allow, multiple profiles are conducted along the crown and flank to assess spatial variability. We also note variations in crown and bed surface properties by obtaining crown measurements in the field and with photos and notes. Further profile locations are typically chosen to duplicate the primary profile as well as to determine variation of aspect and slope angle.

Preceding weather leading to the event is obtained from the nearest weather station. Although weather stations are not typically available at the same elevation or aspect of the avalanche, trends observed at the weather stations can be related to the locations of interest. Dave Tracz of ASARC is analyzing correlations between weather station data and nearby deep slab avalanches. Further insight regarding the path history is gathered from the operation's guides and employees.

The Future

Once the data are compiled over three winters, correlations between the weak layer strength, loading, and weather data will be assessed to find correlations between all observed deep slab avalanches. The ultimate goal of the research is to create a decision support tool that is based on the assessment of key factors leading to deep slab avalanches to aid forecasters in determining whether a deep slab avalanche may occur. The tool will require the user to answer key questions about the snowpack structure and weather information to determine if deep slab avalanches are of concern. Such a tool will be a simple and straightforward approach that might be helpful for avalanche forecasters to reduce the frequency of unexpected deep slab avalanches.

Case Study – CMH Galena, February 2012

Numerous natural deep slab avalanches were observed in the tenure of CMH Galena in early February 2012. They were mostly on southern aspects at elevations above 2200 m in the alpine and typically started on slopes between 35 and 45 degrees. A warming trend was observed during the avalanches, with extended clear skies for the first time in over a month, and near-zero afternoon alpine temperatures.

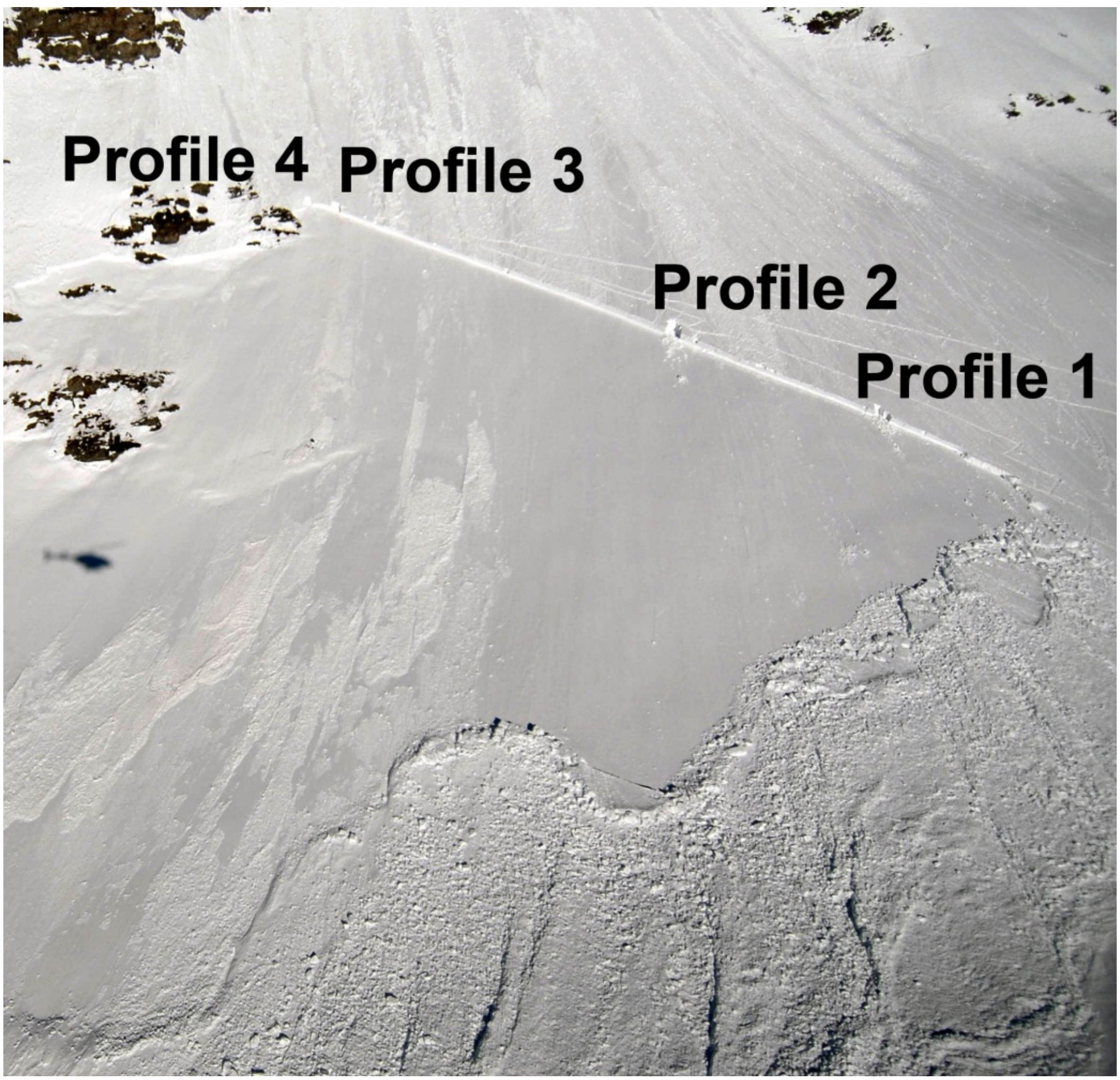
The start zone of one of the avalanches was accessed two days after it released to obtain field data and four profiles were observed along the crown. The failure layer was assessed in each profile, including grain type and size, weak layer depth from surface, two DTs, two PSTs, and a density measurement of the snowpack above the weak layer. Two profiles were observed on a similar aspect and the other two profiles were observed near the thickest and a thin section of the crown. All measurements and tests were performed at least one metre upslope of the crown.

The failure layer was determined to be facets below a crust buried 150 cm in a 270 cm deep snowpack on a 35° slope. The crown depth varied between approximately 30 cm and 150 cm, with thin spots found near rocks. The DTs indicate that spatial variation of the strength of the weak layer was limited at this site. PST results indicate less propagation propensity within the weak layer near the thin section of the crown compared to a deeper snowpack (50% cut length at thick sections and 60% at thin sections), perhaps due to temperature variations more easily penetrating thin sections, allowing for refreezing of free water. Loading varied significantly due to a variable crown thickness, ranging from 65 mm water equivalent at the thin portion of the crown to 340 mm water equivalent at the thickest portion of the crown.

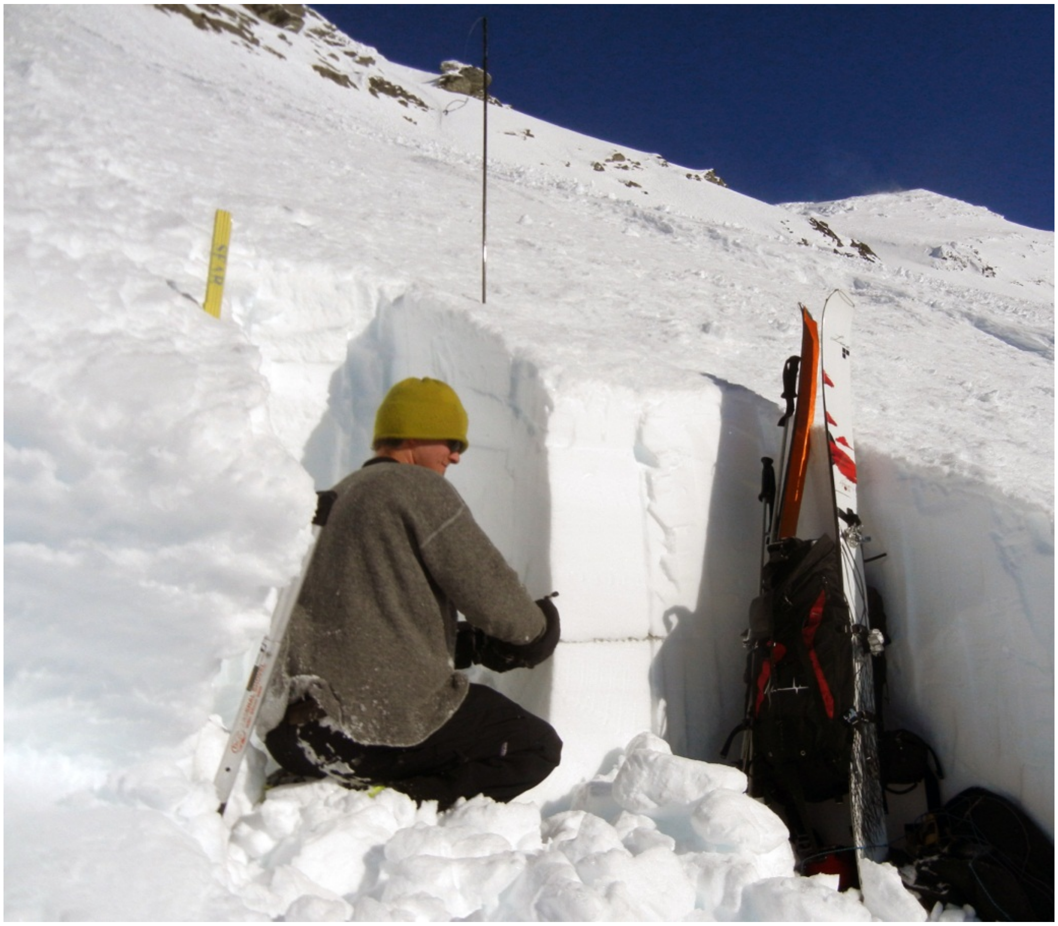
Preceding weather indicated a warming and clearing trend leading up to the event. Being a southwest face, the upper snowpack was heated throughout the day, which was apparent with a well-formed sun-crust by the third day and pin-balling snow from the slopes above. We speculate that that the solar warming impacted the weak layer by reducing its strength in shallow areas of the snowpack. The warming caused free-water and the weakening of bonds until the slab released on the facets below the crust. With further data gathering, correlations of preceding weather, the results of the DTs and PSTs, and loading pattern will be identified between this event and others. Other important terrain features such as elevation and aspect will be important for correlations, as a sunny aspect behaves quite differently than a shady aspect, as does a windward slope to a leeward slope.

Snow profile information and deep tap test and propagation saw test results

		Profile 1	**Profile 2**	**Profile 3**	**Profile 4**
Depth to Weak Layer (cm)		100	142	73	40
Persistent Weak Layer	above	◎◎ (K)			
	1 cm thick	**Ⱥ 1 and ♧ (P-)**			
	below	Ⱥ 0.5 (P)			
DT Results		21 SP	27 SP	21 SP	21 SP
		21 SP	21 SP	21 SP	22 SP
PST Results		45/90 END	79/158 END	65/107 END	55/95 END
		50/103 END	67/140 END	64/108 END	63/108 END



Profile locations at a natural deep slab avalanche at CMH Galena, February 2012



Propagation saw test performed one metre upslope of the crown

Looking Ahead

The help from operations across western Canada is imperative for a positive outcome for this research. Field observations will be continued over the remainder of this winter as well as during the next two winters to obtain as many observations at deep slab avalanches as possible. Human-triggered deep slab avalanches will also be analyzed and analyzed in a similar manner.

Thanks

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