# GLIDE AVALANCHE DETECTION ON A SMOOTH ROCK SLOPE, SNOQUALMIE PASS, WASHINGTON

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ABSTRACT: Glide avalanches involve the full release of the snow pack over a rock slab and are often difficult to forecast. This type of avalanche release is dependent upon local factors such as elevation, aspect, snow cover, weather conditions, and the presence of free water. Glide rate and acceleration of the snow slab is another determining factor for the eventual release of the slab. A smooth rock slab, known as *Rock Face*, is exposed 2.5 km north-northwest of Snoqualmie Pass, Washington adjacent to the Alpental Ski Area. *Rock Face*, at an elevation of 1055 m, has a slope angle of approximately 35° and a northeast aspect. During the winter of 2003-2004, a continuous recording station was installed at the top of the *Rock Face* slope. These data will characterize avalanche processes that control the formation and release of the glide avalanches. Instrumentation includes air temperature, snow temperature, solar intensity, a cable-extension transducer for measuring glide rate and a geophone that will record the precise time of an avalanche. During the 2004 field season, preliminary data collection has been successful, although strain measurements of snowpack glide and failure were not obtained. Since two to three full release avalanches per winter occur at *Rock Face,* the continuous data collectors will record multiple avalanches. By combining observations of time-series of weather data and glide measurements, we will be able to characterize avalanche processes that influence the onset and eventual release of full-depth avalanches.

Keywords: avalanche detection, forecasting, glide

## 1. INTRODUCTION

Glide occurs when the snowpack slips at an interface such as a smooth rock slab (McClung and Schaerer, 1993). This slippage is important to the formation of full-depth or glide avalanches (McClung and Schaerer, 1993). Glide avalanches are often unpredictable and therefore difficult to forecast with precision. Local factors relating to snowpack and weather are important to the formation and subsequent release of such avalanches. A smooth rock slab, known as *Rock Face*, exists 2.5 km north-northwest of Snoqualmie Pass, WA adjacent to the Alpental Ski Area. *Rock Face*, at an elevation of 1055 m, has an average steepness of 35°, and a northeast aspect. The location experiences a maritime snowpack with annual snowfall exceeding 1150 cm and total precipitation averaging 2300 mm during the winter period (October through May). Rain-on-snow events average nearly 550 mm during this period, which is typical for a location of this elevation in the Central Cascade Mountains of Washington State.

During the winter of 2003-2004 a variety of instrumentation was installed above *Rock Face* to begin measuring data related to glide formation and avalanching. This slope was chosen for several reasons: the slope is easily observed from the road and base area at Alpental, access to the starting zone is available in all but highest avalanche danger, and the slope regularly produces 2-3 full depth avalanches per winter. Two snow study plots also exist within the local area. Alpental station #304 is located 0.6 km from *Rock Face* and Snoqualmie Pass station #342 is located 2.5 km from *Rock Face*. These stations collect hourly weather data and daily snowpack information. The instrumentation and local snowpack information will provide data relating to the formation and release of avalanches from *Rock Face*. It is anticipated that these observations will allow the characterization of the avalanche processes that influence the onset and eventual release of full-depth avalanches. Eventually, the understanding of the local

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processes should lead to more accurate forecasting of avalanche releases from *Rock Face* and neighboring slopes which produce glide avalanche events. The following paper and accompanying poster present an overview of the research started in 2003-2004 and provide some insight into the expectations of the research.

## 2. METHODS

A variety of means have been employed to detect and predict glide avalanches including glide shoes, tilt poles and the detection of micro seismic and acoustic emissions (Jones, 2004). Research has also focused on correlating meteorological data with glide rate and release (Clarke and McClung, 1999). Instrumentation installed at *Rock Face* follows these studies in the attempt to correlate meteorological data with that of glide rates and eventual release. For the *Rock Face* study the following information is being recorded on site: air temperature above *Rock Face* and snowpack temperature at the snow-rock interface, both using high-resistance thermistors; solar intensity, as measured by a solar cell; glide rate, using a cable-extension transducer capable of accurately measuring both rate and distance; and seismic information obtained from a Mark L-28 Geophone.

All on-site data, with the exception of the geophone, is recorded to a Campbell Scientific CR-10X data logger every 15 minutes. Glide information from the cable-extension transducer will be recorded using a shorter time interval. Seismic data from the Mark L-28 geophone is recorded to a Ref-Tek logger using a sample rate of 50 samples per second.

Precipitation and snowpack information is measured at Alpental station #304 (960m) and Snoqualmie Pass station #342 (920m). Both stations collect hourly weather data including temperature, precipitation, relative humidity, 24 hour snowfall, and total snow depth. Manual observations at Snoqualmie pass include information relating to snowpack density and water content of new snow, as well as daily snow profiles. A lysimeter located at the Snoqualmie Pass study plot will provide information pertaining to water outflow from the base of the snowpack.

Currently the data collected at *Rock Face* must be retrieved manually from the data loggers. An upgrade to include a radio telemetry link for automated data transfer is planned for the future. Regular snow pits will be conducted at or adjacent to the Rock Face site, in addition to the local snow pack information from the study plots. This will provide more accurate information about snowpack structure, depth, and density at the study location. It is anticipated that the information collected will lead to a better understanding of the factors influencing the onset and release of glide avalanches.

## 3. RESULTS

The temperature sensors, solar cell and geophone were each able to acquire their respective data once installed at *Rock Face*. Most notable results were acquired from the snowpack thermistor and the geophone, although the solar cell did function as expected. The following is a brief description of the expectations and initial results from each of the above mentioned instruments.

The solar sensor used at *Rock Face* is similar to other solar sensors employed by the Washington State Department of Transportation in the Snoqualmie Pass area. It consists of a small solar cell which is used to measure the solar intensity as a function of the cell's electrical output. The cell used at *Rock Face* emits a maximum 600Mv while exposed to direct sunlight. The sensor is located where it will measure sunlight approximate to that which is received on *Rock Face*. The purpose for the sensor is to determine what, if any, effect sunlight and shade have upon the glide rate and release of the snowpack at *Rock Face.* It has been reported that surface cooling may contribute to slab release due to the contraction of the snow surface as it freezes (McClung and Schaerer, 1993). The Alpental Pro Patrol has indicated this may be a possibility as glide releases on *Rock Face* have occurred in the late afternoon shortly after the slope was covered in shadows.

The snowpack thermistor used on *Rock Face* performed to expectations and provided some interesting results. McClung and Schaerer (1993) indicate that the temperature at the base of the snowpack must be at or near 0°C to allow the presence of free water at the snow-rock interface. As expected the temperatures remained at or near 0°C, though slight, yet consistent, changes did occur. These changes tend to follow a diurnal pattern and may be the result of free flowing water at the sensor location. During a period of several days a consistent change occurred indicating the possible presence of free flowing water. Air temperatures during this period indicate the potential for snowmelt as daily maximum temperatures ranged from 6-10° C and lows ranged from -2° C to -4° C. During this period the temperature at the snow-rock interface remained near -0.06° C during the night and then cooled to -0.12° C during the day, after air temperatures climbed above 0° C. This may indicate the presence of free flowing water at the snow-rock interface. The slightly higher temperature of -0.06° C may indicate the presence of an air space at the base of the snowpack which is warmed slightly by the rock slab. The lower temperature of -0.12° C could be caused by the flow of melted snow. The temperature changes during this period remained fairly consistent and followed a pattern similar to that of the air temperature changes. Additional investigation will be necessary to determine whether there is a consistent pattern to this phenomenon.

A Mark L-28 geophone was installed at *Rock Face* to collect data relating to glide and glide release. The geophone was chosen for two reasons: the first is to gather data relating to seismic emissions produced during snowpack glide and avalanche and the second is to act as a backup to the cable-extension transducer, which is the primary glide measuring source. In both cases the geophone will record the precise time of glide and avalanche.

Preliminary analysis of geophone data recorded during the spring of 2004 indicates that information relating to explosives and possibly that of free flowing water were recorded. Sharp spikes in the geophone data were recorded which correspond in time to the detonation of explosives 0.5 km from the recording site. Another series of events possibly indicate the presence of dripping water near the geophone, indicating the movement of free water. During a period of warm weather a series of evenly spaced signals were recorded which may correspond to that of dripping water. More information and analysis is needed as the geophone is capable of recording a tremendous amount of information; much of the data can be discounted as background noise, or that which does not correspond to glide or avalanche movement.

## 4. DISCUSSION

Although no glide events were recorded during the 2003-2004 season other data was acquired. The temperature sensors, solar cell and geophone all functioned properly and recorded their respective data. Each of the instruments recorded information that will contribute to the characterization of the processes which influence the release of full-depth avalanches on *Rock Face*. By measuring meteorological information, glide rates, and corresponding seismic data it is anticipated that a more accurate forecast for glide avalanche releases in the Snoqualmie Pass area will be possible. Additional information about the snowpack obtained from local observations, the neighboring study plots and the WSDOT lysimeter should also contribute to a better understanding of the glide avalanche process.

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## 6. REFERENCES

McClung, D.M. and P.A. Schaerer. 1993. *The Avalanche Handbook*. Seattle, WA, The Mountaineers, 271 pp.

Clarke, J. and D.M. McClung. 1999. Full-Depth avalanche occurrences caused by snow gliding, Coquihalla, British Columbia, Canada. *Journal of Glaciology* 45 (150), 539-546.

Jones, A. 2004. Review of glide process and glide avalanche release. *Avalanche News* 69. Canadian Avalanche Association, Revelstoke, BC, 53-60.