VISUALIZATION OF RUN USAGE HISTORY AND OBSERVATIONS AS A DECISION-MAKING AID DURING PERIODS OF PERSISTENT WEAK LAYER AVALANCHE RISK

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ABSTRACT: Management of persistent weak layer (PWL) avalanche risk to guests and workers in the Helicopter Skiing Industry is of critical importance. PWL avalanches are large, destructive, and can be remotely triggered, making them very difficult to manage. The risk management process of deciding which terrain to ski during periods of PWL is complex and involves many factors. The outcome of this process is ultimately terrain choice, which has several different levels: generation of a daily run list, specific run selection by lead guides in the field, and how each run is skied.

Generation of a run list involves more than an avalanche hazard rating and simple terrain characteristics (Hageli Atkins, ISSW 2016). Knowledge of past terrain usage, avalanche activity history, and relevant snow profiles are all important factors in this decision. Currently this information is available in different sources. Evaluation of this data is very time consuming when generating a run list for an operation with several hundred runs.

The goal of this paper is to present a novel map based visual decision aid for run list terrain selection during periods of PWL risk. A new heatmap algorithm for visualization of terrain usage history is proposed, combined with relevant weather, avalanche observations, and snow profiles. This information is consolidated and displayed on a map to enable efficient evaluation of runs to consider or avoid. Resulting in increased efficiency in run list generation and improved operational safety during periods of PWL risk.

Background: A heatmap is a method of visualizing complex density or usage intensity data using a visual color scale on a GIS map. Heatmaps are now familiar parts of modern life when we use applications such as traffic maps (Google Maps) or outdoor apps (Strava).

This paper will include examples based on data collected at Northern Escape Heli-Skiing during the 2025/26 season using the MtnOps Operational Support System.

KEYWORDS: Avalanche Forecasting, Terrain Usage, Decision Tools.

1. INTRODUCTION

Helicopter skiing operations in Canada manage some of the largest commercial ski areas in the world. Individual heli-ski tenures can span vast geographic areas, in some cases exceeding 10,000 km².

These tenures comprise hundreds of runs spanning multiple elevation bands, aspects, zones, drainages, and even mountain ranges. Avalanche problems and conditions at any given time can vary significantly across different locations within a tenure.

For comparison, the largest lift-accessed ski resort in Canada, Whistler Blackcomb, has approximately 33 km² of skiable terrain. Bella Coola Heli Sports operates within an area of approximately 14,370 km².

Avalanche forecasting and risk management present unique challenges for heli-ski guiding teams due to the vast geographic areas involved and the comparatively limited availability of field observations. Terrain-use decisions within this risk-management process occur at several levels: generation of a daily run list, selection of specific runs by lead guides in the field, and decisions regarding how each run is skied.

This paper focuses on the run-list generation stage of the risk-management process. Recent terrain use, run-coding history, avalanche observations, and snow profiles are all important factors in the run-list generation process (Haegeli, 2004; Sterchi et al., 2019).

This process becomes particularly challenging in the presence of PWL avalanche problems. Unlike short-lived avalanche problems, persistent weak layers may remain relevant for weeks or months and can produce low-probability, high-consequence avalanche conditions (Jamieson and

Schweizer, 2000; Bair et al., 2012). Their distribution may vary considerably with elevation, aspect, terrain, and snowpack characteristics, while obvious signs of instability may diminish as the weak layer becomes more deeply buried (CAA, 2016; Avalanche Canada, 2026).

Persistent avalanche problems are of particular concern to heli-skiing operations. An analysis of 46 fatal avalanche accidents involving 83 fatalities in the Canadian mechanized skiing industry between 1970 and 2020 found that most fatal avalanche accidents were associated with Persistent Slab avalanche problems (Langford and Haegeli, 2020).

Consequently, run-list decisions may require guides to evaluate information collected across large geographic areas and over extended periods associated with persistent avalanche problems. The goal of this paper is to develop a method to efficiently organize, consolidate, and visualize this information to support guiding teams in decision making during run-list generation.

This work was conducted in partnership between the MtnOps Operational Support System and Northern Escape Heli Skiing. Data from the 2025–26 season at Northern Escape Heli Skiing are used for the examples presented in this paper.

2. TENURE SKI RUN MAP

Guides are familiar with viewing topographical maps as part of their training and professional practice. A map-based view of the tenure enables guides to view the ski runs in a familiar manner. Elements of a ski run such as aspect and elevation become immediately clear when viewing a map instead of reading from a run catalog table. Guides can quickly see all the runs in a drainage and build a mental map of runs with similar terrain characteristics.

This mental map enables an interpretation of terrain usage, snow profiles, and avalanche observational data from other representative runs in the decision to open or close runs with similar terrain characteristics.

Traditionally, guiding operations have tenure maps printed and available for viewing in the guides office. Guides also typically have access to a map-based navigation software program with all the runs in the tenure. Each individual ski run in the tenure is overlayed on a topographical map using a line drawn from the start to end of the run. The runs are labeled with their name for identification.

3. RUN LIST VISUALIZATION

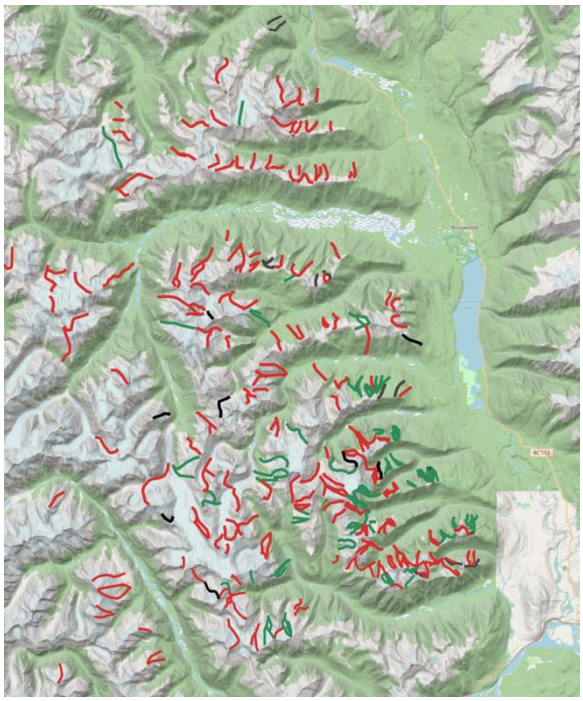
As mentioned in the introduction section, the risk management process of deciding which terrain to ski is complex and involves many factors. The outcome of this process is a daily operational run list.

The run list being developed by the guiding team is visually represented on the map by color coding the ski run lines based on the scheme outlined in Table 1.

Table 1: Run list coding colour scheme.

Run List Code	Colour
OPEN	GREEN
CLOSED	RED
NOT-CONSIDERED	BLACK
SNOW-SAFETY	YELLOW

Figure A: Northern Escape Heli Skiing run list from 08-Mar-2026



4. DATE RANGE FILTERS

Recent history of run usage, run coding, snow profiles, and avalanche observations are used by guiding teams in the evaluation of individual ski runs during the run list generation process.

The length of the date range for which run usage and observations are relevant depends on the type and state of the current avalanche problems (Øien et al., 2023). Having the ability to filter the date range reduces the volume of data to be reviewed and enables the guiding team to focus on the relevant information. In the case of persistent weak layers, the information date range can be two weeks or more.

The interface described here provides several present date range filters (1 day, 7 days, 2 weeks, 30 days) and the option for users to customize the exact range.

5. ZONE FILTERS

Run usage and observation data is further filtered based on predefined zones within the tenure. This is to handle the geographic diversity of a large heli-ski tenure.

6. RUN USAGE HISTORY

Recent run usage history plays a significant role in the run list generation process. Guiding teams are more likely to open a run with which they have previous recent skiing experience on it (Sterchi, Haegeli, and Mair, 2019).

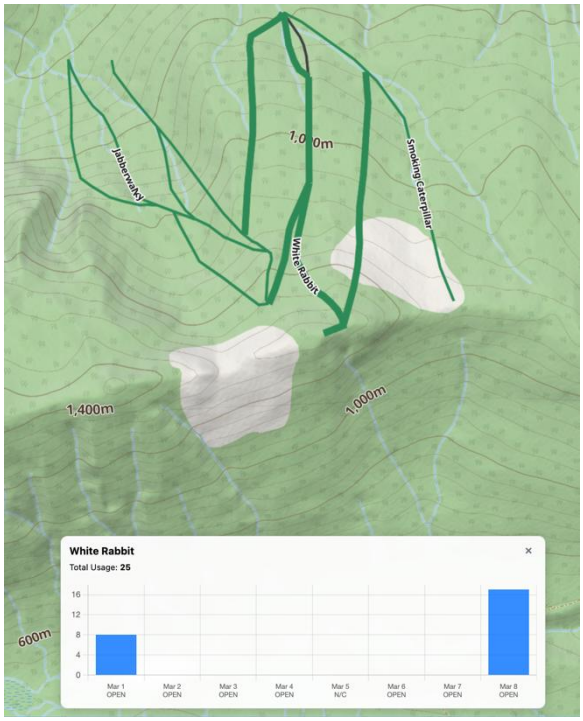
This recent run usage data is integrated into the MtnOps system in three different ways:

- Run Usage Chart
- Run Usage Heatmap
- Run Usage Rose

6.1 Run Usage Chart

Detailed run usage history for each individual run is obtained from the MtnOps operational support system. When selecting a ski run for run list evaluation, a graph is displayed indicating the run usage totals for each day over the usage history date range.

Figure C: Run Usage Chart Example



6.2 Run Usage Heatmap

An option is available which will turn the ski run map into heatmap visualization mode. The brightness of each ski line is correlated with the run usage during the period specified in the data range filters. Guides can quickly visualize which runs have been skied in the tenure.

While a run usage heatmap representing total recent run usage would be useful, it would not differentiate runs which have had usage at the beginning of the period vs runs which have more recent usage (i.e. 1 or 2 days ago).

Given the strong relationship between recent skiing and run-list coding identified by Sterchi et al. (2019), and the results of the present analysis indicating that more recent run usage has an even stronger association with a run being coded open, a recency-weighted run-usage history algorithm is proposed.

6.3 Run Usage Heatmap Algorithm

To model the higher relevancy for more recent run usage vs older run usage within the period specified in the data range filters, an exponential decay function is used. This function decays at the rate of 80%. In other words, yesterday's usage counts at 100%, two days ago 80%, three days ago 64%, etc.

The weighted run usage heatmap score for each run is then normalized into a value between 0 and

100 for display on the map. Where 0 has no usage and 1-100 represent increased usage.

The normalized usage score for each run is displayed on the map with a heatmap intensity color based on the legend illustrated in Figure D.

Figure D: Run Usage Heatmap Legend

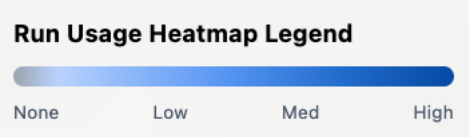


Figure E: Run Usage Heatmap For Northern Escape Heli Skiing. (Date Range Filter: 1-Mar-2026 to 8-Mar-2026):

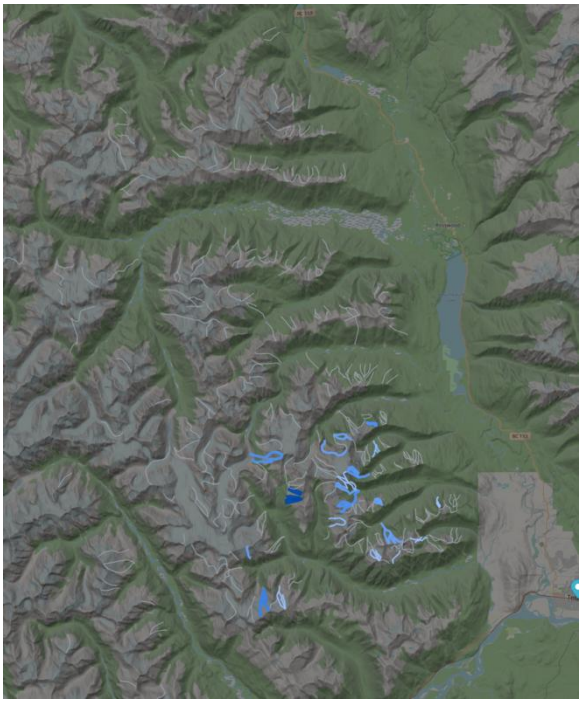


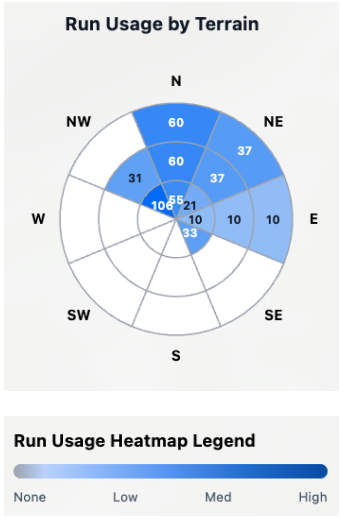
Figure F: Zoomed in view of Figure E. Note run name become visible when zooming in for added context:

7. RUN USAGE ROSE

A consolidated view of all terrain usage by aspect and elevation within a zone and date range is provided using a new elevation and aspect rose diagram called the “Run Usage Rose’. The ‘Run Usage Rose’ has cardinal and intercardinal aspects for each elevation band (Alpine, Treeline, and Below Treeline).

Each aspect and elevation section of the rose has a number and a colour. The number is the sum of usage for all runs on this aspect and elevation band within the zone filter and date range. The color is the representation of the total usage amount on a heatmap color scale.

Figure G: Run Usage Rose for Northern Escape Heli. (Date Range Filter: 1-Mar-2026 to 8-Mar-2026)



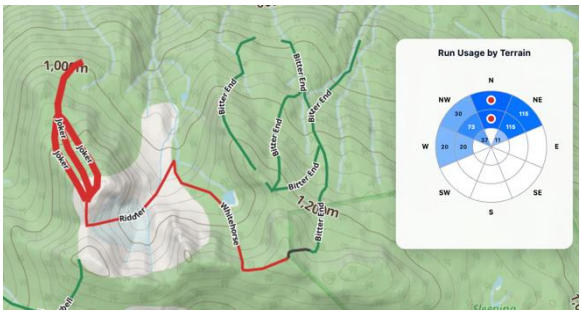
Given that a single run can span multiple aspects and elevations, the usage amount for that run is included in the total for each of the aspects and elevations. For example, the run 'White Rabbit' was skied by 10 people. White Rabbit is east facing and includes alpine, treeline, and below tree line terrain. The usage amount of 10 is included in each of the 3 sections.

7.1 Selected Run on Run Usage Rose

When developing the daily run list, the selected run for consideration is heighted on the map and displayed on the rose. A circle is displayed on the rose representing each each aspect and elevation band that the run travels through. The color of the circle is the current run coding (e.g. RED for CLOSED).

For example, the ski run "Joker" is under evaluation in the Run List discussion. "Joker" is a North Aspect run in both Treeline and Below Treeline elevation bands. The run is currently 'CLOSED'. When the guiding team selects "Joker" for evaluation, a red circle appears on the 'Run Usage Rose' in the North Treeline and Below Treeline sections. This very clearly shows that there have been recent usage of other runs with similar aspect and elevation.

Figure H: Northern Escape Heli Skiing run "Joker" visualized on Run Usage Rose (Date Range Filter: 1-Mar-2026 to 8-Mar-2026).



A caution message is displayed if the run travels through aspects and elevations for which there is no recent usage.

For example: The run "Poison Beauty" is on a South East aspect traveling through Treeline and Below Treeline terrain. When selected, the red circles appear in the sections without any recent terrain usage. A caution message is displayed.

Figure I: Caution message displayed for Northern Escape Heli Skiing run "Poison Beauty" visualized on Run Usage Rose (Date Range Filter: 1-Mar-2026 to 8-Mar-2026).

8. SNOW PROFILES

As noted above, recent snow profiles are an important factor in the run list generation process. Visualizing their locations relative to runs being considered helps guides assess how relevant each snow profile is to the terrain and conditions associated with a particular run.

Recent snow profiles are displayed on the run list map using a snowflake icon that can be clicked on for more details.

Figure J: Snow profiles at Northern Escape Heli Skiing (Date Range Filter: 1-Mar-2026 to 8-Mar-2026)

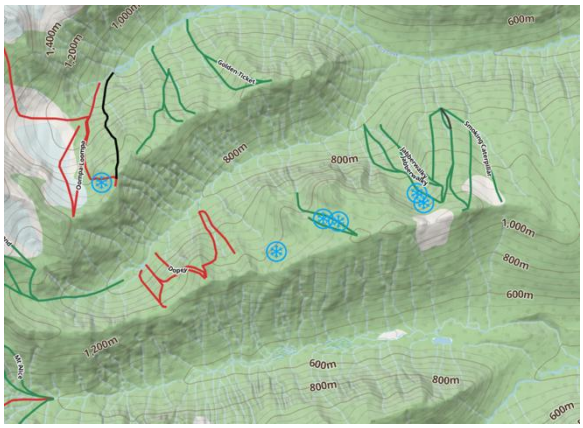
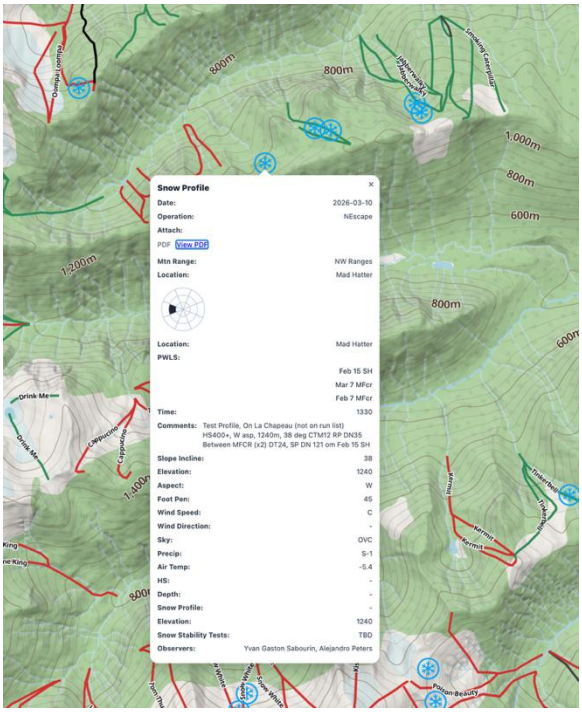


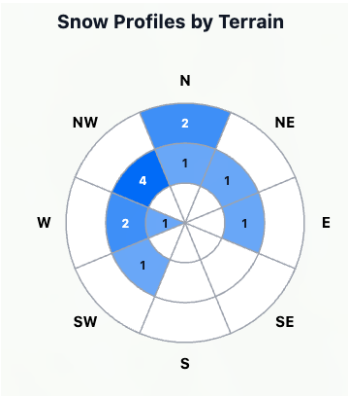
Figure K: Snow profile detailed information displayed



8.1 *Snow Profile Rose*

A “Snow Profile Rose” is created which provides a consolidated visualization of snow profiles. The number in section represents the total number of profiles observed in that aspect and elevation within the zone and date range. The number is then mapped to a heatmap color scale providing a further visual aid.

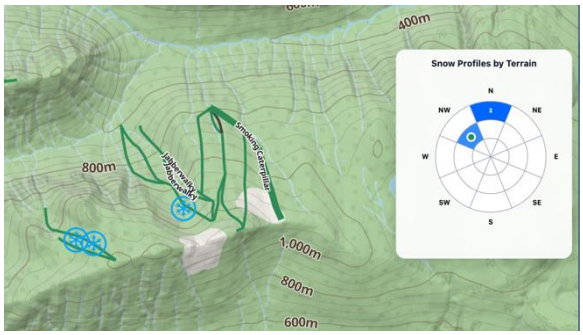
Figure L: Snow profiles observed at Northern Escape Heli Skiing (Date Range Filter: 1-Mar-2026 to 8-Mar-2026).



8.2 *Selected Run on Snow Profile Rose*

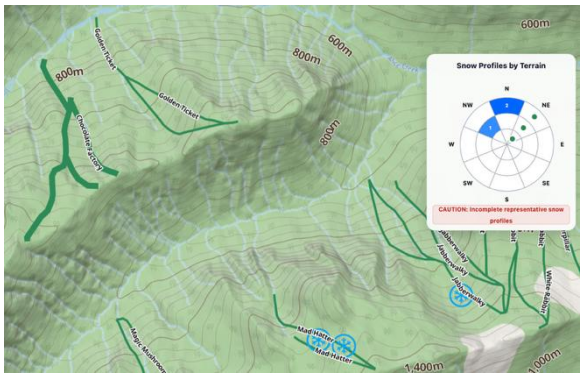
The selected run for evaluation is also displayed on the “Snow Profile Rose” with a circle in each section based on the aspects and elevation bands the run travels through.

Figure M: “Smoking Caterpillar” run at Northern Escape Heli Skiing. Run is ‘OPEN’ and travels through NW TL Terrain.



A caution message is displayed if the run travels through aspects and elevation bands without any recent snow profile observations.

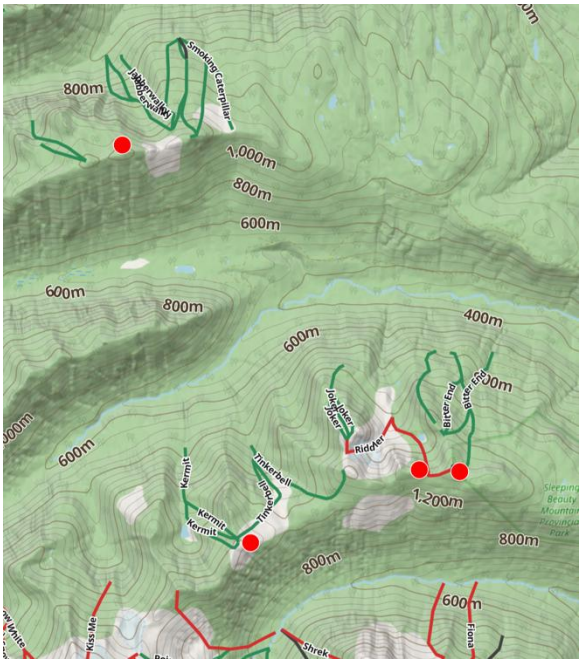
Figure N: “Chocolate Factory” run travels through all elevation bands on a NE aspect without any representative snow profiles. A caution message is displayed.



9. AVALANCHE OBSERVATIONS

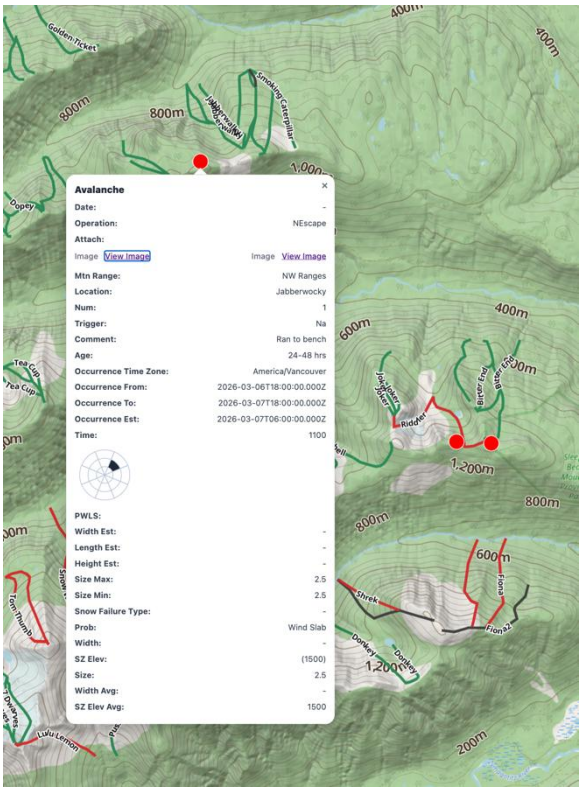
Avalanche observations that are reported, during the date range period, are visualized on the run list map view with red circles.

Figure O: Avalanche observations at Northern Escape Heli Skiing (Date Range Filter: 1-Mar-2026 to 8-Mar-2026).



Additional details on the avalanche observed can be obtained by clicking on the icon.

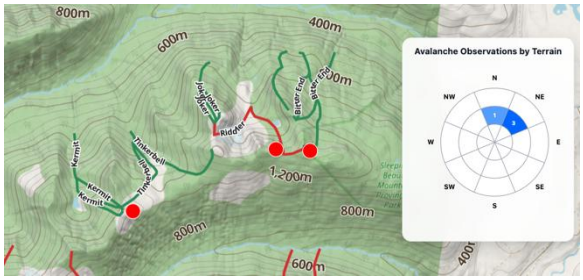
Figure P: Avalanche observation detailed information displayed



9.1 Avalanche Observation Rose

A consolidated view of all recent avalanche observed are provided in a new “Avalanche Observation Rose”. The rose contains the total number of recent avalanches observed for each aspect and elevation band in the zone and date range period. The total numbers are also displayed with a heatmap color scheme for ease of visualization.

Figure Q: Avalanches observed at Northern Escape Helli Skiing and visualized in the “Avalanche Observation Rose”

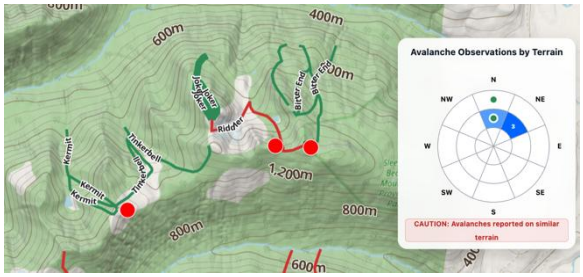


9.2 Selected Run on Avalanche Observation Rose

When a single run is selected it is displayed on the rose with a circle for each aspect and elevation band traveled through.

When a run travels through aspects and elevations where there have been recent avalanches observed, a caution message is displayed.

Figure R: Caution message is provided for the ski run “Joker”, which travels through terrain where avalanches have been observed recently.



10. CONSOLIDATED MAP VIEW

The complete consolidated view includes the following key elements on a single map-based visualization:

- Avalanche Hazard Rating History
- Run List
- Run Usage Heatmap
- Run Usage Chart
- Run Usage Rose
- Snow Profile Observations

- Snow Profile Rose
- Avalanche Observations
- Avalanche Observation Rose

Figure S: Complete view of run list with visualization run usage and observations.

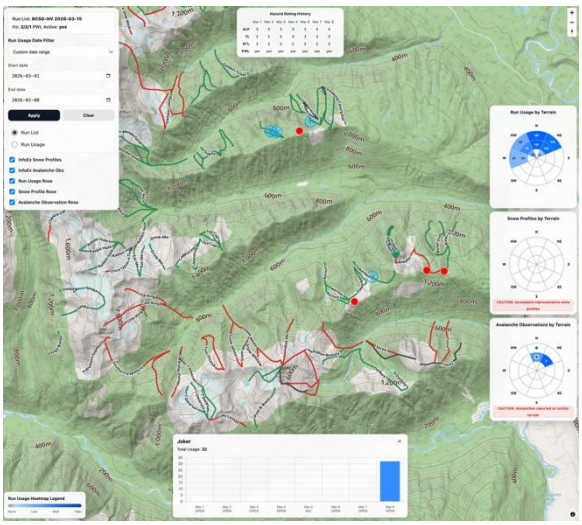
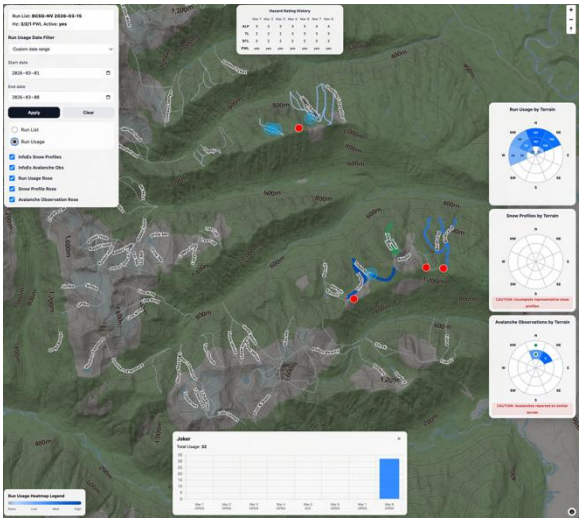


Figure T: Complete view of run usage heatmap with snow profile and avalanche observations.



11. CONCLUSION

Using concepts such as run usage heatmaps and aspect-elevation roses, this new map-based visualization provides a single consolidated view of heli-skiing terrain and relevant operational data.

The goal of this work is to provide a decision-making aid for run list generation in general, and especially during periods of PWL avalanche risk.

The system will be used by guiding teams at Northern Escape Heli Skiing during the upcoming 2026–27 season. Further surveys and studies will be conducted to evaluate its effectiveness.

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