USING CROWDSOURCED DATA TO UNDERSTAND TERRAIN USAGE PATTERNS OF BACKCOUNTRY RECREATIONAL USERS

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ABSTRACT: Avalanche Canada's Mountain Information Network (MIN) is an online platform that allows users to share real-time information with the backcountry community and public avalanche forecasters. Users can submit weather, snowpack, and avalanche observations, as well as report avalanche incidents. MIN reports also contain fields for reporting terrain use and avoidance. These reports are geotagged and displayed on an interactive map on Avalanche Canada's website. During the 2015-16 winter season, 1309 reports were submitted to the MIN. These reports provide insight into spatial and temporal usage patterns of backcountry users. Terrain usage and avoidance data are evaluated against various other field conditions reported on the MIN. The usage and avoidance data are also compared with Avalanche Canada's daily avalanche danger ratings. By comparing these datasets, we can link public backcountry usage patterns to professional avalanche hazard assessments. Data shows users' terrain preference for mellow slopes and open trees, while commonly avoiding alpine slopes, convex slopes, and steep slopes. As avalanche danger increases, we see an increase in avoidance of alpine, convex, and steep slopes, and an increase in usage of mellow slopes and open trees. This research will lead to an improved understanding of how backcountry recreational users utilize terrain based on various field conditions and based on avalanche danger ratings in the public bulletins.

KEYWORDS: Public forecasting, crowdsourcing, travel behavior, terrain use, avalanche danger index

1. INTRODUCTION

Crowdsourcing winter backcountry field observations has become increasingly popular in recent years with internet data sharing platforms being developed in several US states, Norway, Iceland, and Canada (Tremper, 2014; Christian, 2014; Ekker, 2013). Many other public avalanche forecasting operations also encourage users to submit observations to their forecast office for the sole purpose of improving public forecasts. Avalanche Canada's platform is called the Mountain Information Network (MIN) and its primary purpose is for recreational users to share real time field observations with other users as well as with public avalanche forecasters.

Crowdsourced field observations also allow us to better understand how recreational users are travelling in avalanche terrain. Previous work to understand recreational travel behavior and decision making utilized surveys in order to obtain information from recreational users (Hendrikx, 2014; Haegeli, 2010), used GPS tracking to follow users through terrain (Hendrikx, 2013), or a combination of the above (Martensson, 2014). With the recent advent of publicly crowdsourced observations, we can now analyze amateur travel data without the need for surveys or GPS tracking.

In Avalanche Canada's forecasting office, crowdsourced field observations serve several roles. The map-based nature of these observations help forecasters interpret spatial variability of conditions across large forecast regions. These reports also help fill in data gaps in data sparse regions. The upcoming 2016/17 season will see the implementation of "hot zone reports" in which forecasters will provide conditions and travel guidance in data sparse regions outside our normal forecast regions. These hot zone reports will rely heavily on MIN reports (Storm, 2014). Over a longer time period, crowdsourced reports help us understand where backcountry users are recreating and allow us to better target our forecasting products.

2. DATA

2.1 *Mountain Information Network user submitted data*

For the 2014/15 and 2015/16 winter seasons, Canadian backcountry users have been encouraged to submit field observations using Avalanche Can-

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ada's phone app or directly to Avalanche Canada's website (www.avalanche.ca). These reports are geotagged and displayed on an interactive map on Avalanche Canada's homepage. The reports can then be shared on social media.

The MIN saw a substantial increase in its second season with a total of 1309 posts, up from 397 posts in the 2014/15 season. The 2015/16 season also saw the submission of over 1100 photos.

During the 2014/15 season, the MIN was limited to a single reporting option, the Quick Report. The 2015/16 season saw the addition of four new types of technical reports which includes Snowpack, Weather, Avalanche, and Incident Reports (Table 1).

Table 1: Number of unique user submitted MIN reports by report type

MIN Report Type	*2014/15*	*2015/16*
Quick Report	397	1221
Avalanche Report	~	127
Snowpack Report	~	163
Weather Report	~	137
Incident Report	~	34

Due to the relatively small number of technical reports submitted thus far, this paper focuses on the Quick Report. The Quick Report has six main sections including riding quality, snow conditions, terrain utilized, terrain avoided, weather conditions, and avalanche conditions. Each of these sections has a set of predefined options which are selected using check boxes. The Quick Report also has a free form comment section and the option to submit photos.

2.2 Public forecast regions

There are a total of 23 public forecast regions in Canada. Avalanche Canada operates 12 primary forecast regions in western Canada which have daily avalanche bulletins. Another six regions have daily public avalanche bulletins including four operated by Parks Canada (Glacier, Banff/Yoho, Little Yoho, and Jasper), Kananaskis Country which is operated by Alberta Parks, and Whistler-Blackcomb. Other regions with less than daily bulletins include the Yukon, Chic Chocs (Quebec), North Rockies, Waterton National Park, and Vancouver Island. The focus of this paper is the 12 primary Avalanche Canada forecast regions.

2.3 Avalanche Canada public avalanche bulletins

Avalanche Canada publishes daily avalanche bulletins from late-November to late-April for its 12 primary regions. Public avalanche forecasters use the conceptual model of avalanche hazard (Statham, 2010a), which outputs avalanche problems as components of avalanche hazard, and the North American public avalanche danger scale (Statham, 2010b). Bulletins are created using AvalX software which was built by Parks Canada, Avalanche Canada, and Alberta Parks, and was released in 2011 (Statham, 2012).

Daily avalanche bulletins contain up to three detailed avalanche problems for each region as well as danger ratings for three elevations bands. Each of the avalanche problems includes specific information on the location of the problem within the terrain, the likelihood of triggering the problem, the expected size range of an avalanche if triggered, and terrain travel advice related to the problem. The avalanche bulletin also includes detailed text descriptions of avalanche activity, snowpack details, and a regional weather forecast.

3. METHODS

3.1 Mountain Information Network user submitted data

Two different MIN datasets were created for this project. The first includes all the MIN Quick Reports. The second dataset is a subset of the first and includes all the MIN Quick Reports which were located in Avalanche Canada's 12 primary forecast regions.

In order to classify the MIN posts by regions, all the MIN data was entered into GIS software along with the forecast region polygons. Each MIN post was then classified by the region in which it was submitted (Table 2). Avalanche Canada's 12 primary forecast regions include the following: Cariboos, Kootenay Boundary, Lizard Flathead, North Columbia, North Shore, Northwest Coastal, Northwest Inland, Purcells, South Coast Inland, Sea-to-Sky, South Columbia, and South Rockies.

Table 2: MIN post frequency by region, 2014/15 and 2015/16 seasons.

Region	*Number of MIN Posts*
Banff/Yoho National Park	130
Cariboos	77
Chic Chocs	52
Glacier National Park	87
Jasper National Park	16
Kananaskis Country	57
Kootenay Boundary	122
Little Yoho National Park	10
Lizard Flathead	90
North Columbia	73
North Rockies	133
North Shore	28
Northwest Coastal	56
Northwest Inland	56
Purcells	56
South Coast Inland	144
Sea to Sky	52
South Columbia	63
South Rockies	68
Waterton National Park	6
Whistler Blackcomb	73
Yukon	143
No Region	114
Total	1706

3.2 Avalanche Canada forecast date ranges

The subset of the MIN data was limited to the periods when Avalanche Canada was actively producing public avalanche forecasts. The 2014/15 season ran from November 22, 2014, until April 20, 2015. The 2015/16 season ran from November 21, 2015, until April 25, 2016. Any MIN posts that were submitted outside these time periods were excluded from the avalanche danger analysis.

3.3 MIN dataset for avalanche danger

Once all the MIN posts were filtered based on the forecast region and date range, each MIN post was merged with the public forecasting data based on the date and region. Each MIN post has a set of danger ratings and up to three avalanche problems with the specific problem details.

MIN posts that did not contain a quick report were also excluded from the dataset. The resulting filtered dataset consists of 775 quick reports.

3.4 Quick report details

Each quick report consists of six unique sections, all of which are optional. Each section was only included in the dataset if at least one of the checkboxes was selected from that section. The total number of completed sections in the dataset are shown in Table 3.

Table 3: Completed sections of MIN quick reports (n=775)

Quick report section	*Number of completed sections*
Riding quality	751
Snow conditions	622
Terrain utilized	587
Terrain avoided	444
Weather	747
Avalanche conditions	434

3.5 Avalanche Danger Index

Public avalanche forecasts include three danger rating for the alpine, treeline, and below treeline. In order to represent a date with a single danger rating, we created an Avalanche Danger Index (ADI), defined as the sum of the danger ratings for the alpine and treeline. The range of possible values of the ADI extend from 2 (Low, Low) to 10 (Extreme, Extreme). Our dataset has maximum values of 8 (High, High) since the extreme danger rating (5) was not used during the study period.

The ADI attempts to represent the danger rating for the two elevation bands where the majority of backcountry recreation occurs. Below treeline was excluded because danger ratings are typically lower at this elevation due to unique weather and snowpack conditions. Below treeline rarely has a higher danger rating than the higher elevation bands. Danger ratings are also commonly omitted from below treeline in many regions during the early and late parts of the forecasting season when the snowpack is below threshold for avalanches. For these reasons, below treeline ratings were excluded from the ADI.

4. RESULTS

4.1 MIN quick reports and terrain use

The percentage of each type of terrain avoided is calculated for all days when each of the other various conditions on the quick report were observed and reported (Table 4). The first section of the table relates to conditions that strongly indicate unstable avalanche conditions. Some results are expected. For example, 70% of reports indicated avoiding convex slopes when slab avalanches had been observed today or yesterday, and 80% of reports avoided convex slopes when whumpfing had been observed. However, two unexpected results can be noted. Open trees were only avoided in 5-6% of reports when unstable conditions were present, and sunny slopes were only avoided 33% of the time when a rapid temperature rise to near zero degrees or wet surface snow was noted.

To better understand what these trends mean, it is helpful to consider the general terrain avoidance preferences regardless of conditions. This is indicated in the bottom line of the table, which shows the percentage of terrain avoidance for all days in the dataset. It provides a seasonal average which can be used as a baseline when looking at the specific conditions. This baseline shows convex slopes are the most avoided type of terrain (66%) along with steep slopes (59%) and alpine slopes (47%). Open trees are the least avoided type of terrain (3%) with cut blocks second (6%).

The second and third parts of Table 4 indicate terrain avoided for different snow and riding conditions, respectively. 75% of reports indicated avoiding convex slopes when conditions were described as deep powder, which is higher than the baseline figure of 66% for generally avoiding convex slopes. However, fewer reports avoided steep slopes in deep powder conditions (56% of reports compared to a baseline of 59%). Not surprisingly, 78% of reports indicated avoiding steep slopes when conditions were described as terrible.

The fourth part of Table 4 indicates terrain avoided for different weather conditions. Compared to the baseline, alpine slopes are most likely to be avoided when the day was stormy or when the day was wet. Alpine slopes were least likely to be avoided on sunny days. Steep slopes are most likely to be avoided on warm or wet days, and least likely to be avoided on cold days.

Table 5 shows the percentage of terrain used on days where a specific type of terrain was avoided. The bottom line of the table shows the percentage of terrain used for all days in the dataset. Mellow slopes (67%) and open trees (63%) are the most utilized types of terrain. The least used types of terrain are cut blocks (9%), convex slopes (16%), and sunny slopes (19%).

When alpine slopes or convex slopes were being avoided, we see an increase in the use of mellow slopes and open trees. When steep slopes were being avoided, we see an increase in the use of mellow slopes. Dense trees are the mostly likely terrain to be used when open trees were being avoided.

4.2 Avalanche Danger Index and terrain use

The second part of this project was to couple the MIN quick reports with the Avalanche Danger Index from the public forecasts. Figure 1 shows the percentage of each type of reported terrain avoided for each ADI value. Convex slopes, steep slopes, and alpine slopes all show an increasing trend of avoidance with increasing ADI. A slight increase is noted in the avoidance of cut-blocks with increasing ADI. There is almost no discernible trend for the avoidance of open trees (which as previously mentioned, has a very low baseline level of consideration). The avoidance of sunny slopes appears to decrease with an increase in the ADI.

Figure 2 shows the percentage of each type reported terrain used for each ADI value. Mostly we see the trends mirroring the terrain avoidance patterns in Figure 1, except for sunny slopes, which see a marked decrease in terrain use with increasing ADI. Additionally, trends are available for mellow slopes and dense trees. As expected, mellow slopes were reportedly used more often during periods with higher ADI. Surprisingly, the use of dense trees does not appear to change much with a change in the ADI.

Table 4: Percentage of reported terrain avoided based on various avalanche, snow, riding, and weather conditions from MIN quick reports, 2014/15 and 2015/16 seasons. The column labelled *n* represents all days where that specific condition was observed.

		Percentage of Reported Terrain Avoided					
For all days where:	n	Alpine Slopes	Convex Slopes	Cut blocks	Open Trees	Steep Slopes	Sunny Slopes
Slab avalanches observed today or yesterday	271	51%	70%	7%	6%	63%	14%
30cm + of new snow, or significant drifitng, or rain in the last 48 hours	259	56%	73%	8%	5%	63%	11%
Whumpfing or drum-like sounds or shooting cracks	188	53%	81%	10%	6%	70%	10%
Rapid temperature rise to near zero degrees or wet surface snow	180	46%	64%	11%	5%	62%	33%
Snow conditions were crusty	207	47%	62%	9%	1%	67%	22%
Snow conditions were deep powder	171	51%	75%	5%	4%	56%	8%
Snow conditions were hard	72	39%	67%	4%	1%	61%	18%
Snow conditions were heavy	192	54%	67%	9%	7%	69%	20%
Snow conditions were powder	582	46%	66%	6%	2%	57%	15%
Snow conditions were wet	137	53%	64%	10%	7%	70%	24%
Snow conditions were wind affected	352	40%	70%	4%	1%	59%	14%
Riding quality was amazing	187	48%	67%	4%	2%	50%	12%
Riding quality was good	441	45%	67%	6%	2%	58%	13%
Riding quality was OK	196	50%	62%	6%	5%	66%	23%
Riding quality was terrible	51	51%	65%	16%	6%	78%	20%
The day was cloudy	468	52%	68%	7%	3%	59%	15%
The day was cold	117	42%	73%	5%	2%	48%	9%
The day was foggy	129	47%	73%	13%	7%	60%	12%
The day was stormy	210	58%	68%	5%	4%	61%	6%
The day was sunny	398	34%	62%	6%	3%	60%	23%
The day was warm	271	52%	63%	6%	4%	65%	24%
The day was wet	63	59%	76%	13%	8%	71%	11%
The day was windy	253	48%	71%	4%	2%	61%	9%
All Days	883	47%	66%	6%	3%	59%	16%

Table 5: Percentage of reported terrain used based on terrain avoided on the same day from MIN quick reports, 2014/15 and 2015/16 seasons. The column labelled *n* represents all days where that type of terrain was avoided.

		Percentage of Reported Terrain Used							
All days when users reported avoiding terrain:	n	Alpine Slopes	Convex Slopes	Cut blocks	Dense Trees	Mellow Slopes	Open Trees	Steep Slopes	Sunny Slopes
We avoided alpine slopes	415	2%	12%	12%	40%	76%	75%	28%	12%
We avoided convex slopes	580	36%	2%	9%	31%	73%	68%	28%	15%
We avoided cut blocks	55	23%	13%	0%	40%	91%	62%	23%	13%
We avoided open trees	26	21%	4%	0%	71%	71%	17%	17%	0%
We avoided steep slopes	524	32%	7%	8%	27%	85%	64%	5%	17%
We avoided sunny slopes	137	35%	15%	9%	32%	68%	65%	39%	5%
All Days	1141	38%	16%	9%	28%	67%	63%	34%	19%

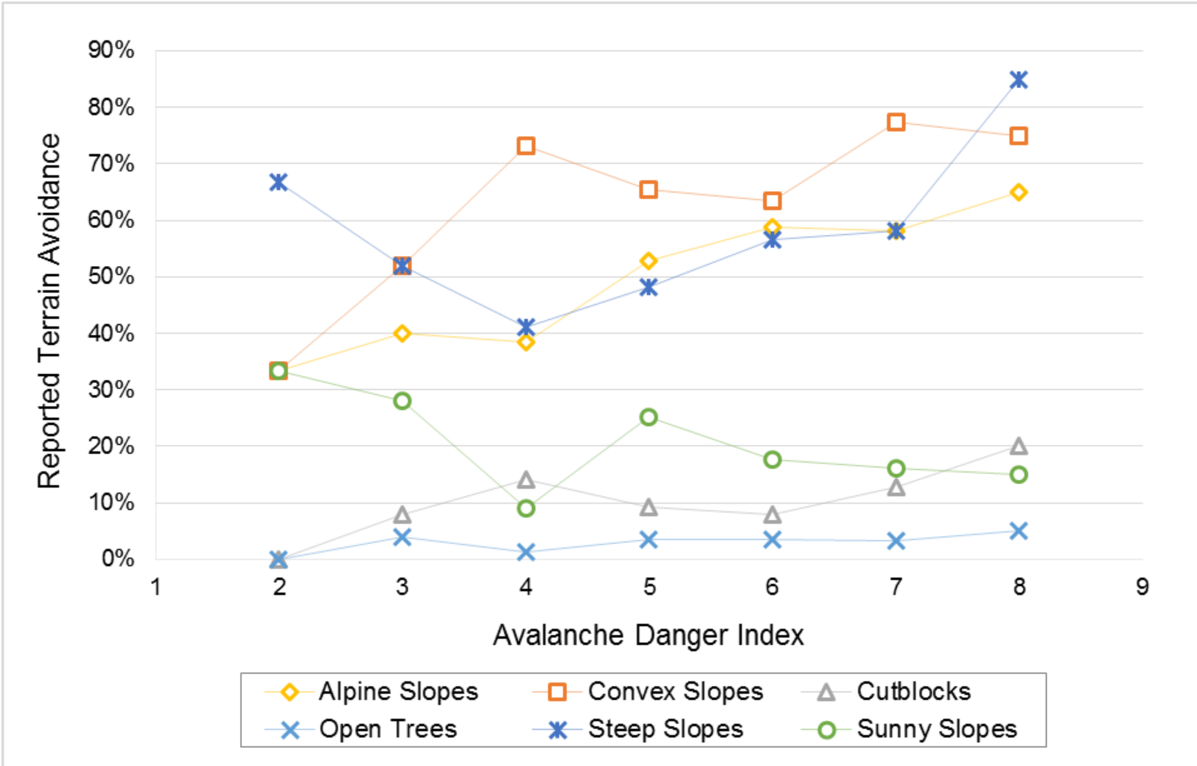

Figure 1: Percentage of reported terrain avoided from MIN quick reports by Avalanche Danger Index.

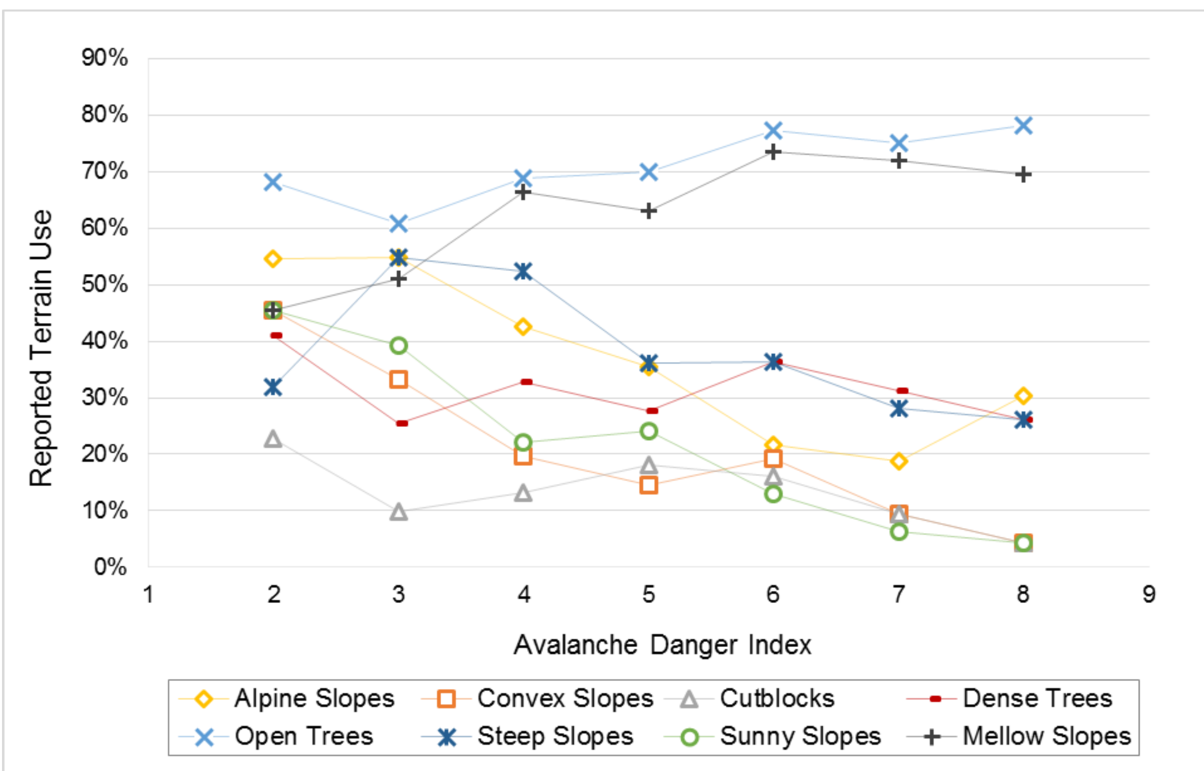

Figure 2: Percentage of reported terrain used from MIN quick reports by Avalanche Danger Index

5. DISCUSION

5.1 Use and avoidance of open trees

Open trees saw the least amount of avoidance overall (Table 4) and even saw a slight increase in use with increasing hazard (Figure 2). This is concerning because open trees are a common terrain feature for avalanche accidents. Between 1997 and 2007, 24% of avalanche fatalities in Canada occurred in sparse trees (Jamieson, 2011). According to Atkins (2012), "if there is room to ski and link turns, there is room to release an avalanche." If a person is caught in an avalanche in trees, there is an increased likelihood of trauma. Trees were the most common type of object hit in traumatic avalanche fatalities (68%) in a 21 year study period (Boyd, 2010).

There are several possible reasons why more users did not report avoiding open trees in this dataset. It may be that these terrain choices are not defined clearly enough on the quick report. Since steep and mellow terrain are also listed as separate options, there may be a perception that selecting open trees on the quick report implies that it only includes the use of moderately sloped open trees. There may be value in a more detailed study which considers multiple terrain selections to get a better understanding of how users are reporting the use of open trees. It may also be a more systemic problem with recreational users' perception of the avalanche risk associated with the use of open trees. This type of terrain is not always clearly identifiable as avalanche terrain to new or inexperienced users. In this case, improved awareness and education are the likely solutions. Public avalanche forecasters should be aware of the low reporting rates of the avoidance of open trees and cater products accordingly when the specific conditions warrant it.

5.2 Deviation of reporting rates from the seasonal average

The largest deviations in terrain avoidance from the baseline was 19% and was observed for steep terrain when conditions were reported as terrible (increase from 59% to 78%). While this deviation is substantial, a general trend shows there to be a lack of substantial changes in critical terrain avoidance (alpine, convex, and steep) in response to observations of potential avalanche instabilities. This could suggest that many people have a general set of terrain selection rules that they follow regardless of conditions. If so, it implies there is still significant scope for terrain-oriented education and outreach in Canada. It could also suggest that the methods used in this report are too simple to capture the subtly of terrain selection for avoiding avalanche hazards. This work looks at single terrain choices against single indicators of avalanche hazard. A more complex model needs to couple multiple terrain selection choices from the MIN reports and needs to account for more specific locations of avalanche hazard which may include several potential indictors. Adding avalanche problems from the public forecasting dataset may assist this analysis.

5.3 None of the above MIN reporting option

None of the MIN quick reports had all six of the reporting sections completed in our dataset. Several reports had zero sections completed as the users chose to only use comments and/or upload photos. Part of the difficulty in interpreting quick report sections that were not completed is that it is not possible to determine if the section was not completed because none of the conditions were met or because the user was not interested in reporting that section.

It is possible that the motivation to report terrain avoidance versus terrain use also depends on the ADI. When avalanche hazard is low, users' mindsets are likely to be tuned more to "what kind of terrain can I ride", whereas when the hazard is high, users are more likely to be assessing what terrain they will need to avoid to stay safe.

The addition of a choice for "none of the above observed" should help indicate whether a user assessed the question and decided no conditions applied, as opposed to whether they ignored the question altogether. This will help address the problem of missing data in the dataset. This is especially true for the section on avalanche conditions but may also be useful for snow conditions and weather conditions, along with terrain use and avoidance. The addition of a coupled blank text field could also be useful for better understanding possible conditions or terrain choices that are not included as options in the current quick report.

6. SUMMARY

This project has shown the potential usefulness of Avalanche Canada's MIN dataset for understanding how recreational users utilize terrain under various conditions and danger ratings. The data shows that mellow slopes and open trees are the most commonly used types of terrain while alpine slopes, convex slopes, and steep slopes are the most likely to be avoided. For each of the various avalanche, snow, weather, and riding conditions on the MIN, we can assess the change in the percentage of each type of terrain avoided. For example, when whumphing or shooting cracks are observed, we see the most substantial increases in terrain avoidance for steep slopes and convex slopes. Finally, terrain avoidance and use were compared against avalanche danger from the public bulletins published by Avalanche Canada. As avalanche danger increases, we see an increase in the avoidance of convex slopes, steep slopes, and alpine slopes, and an increase in the use of mellow slopes and open trees. The lack of avoidance of open trees with increasing avalanche danger is the most concerning finding in this report.

The analysis done for this project was relatively simple and needs a more advanced research approach in the future. As the dataset grows, an increase in the reliability of the MIN data is expected as more variance in backcountry avalanche, weather, snowpack, and riding conditions are encountered and reported. A larger dataset should also allow an increase in potential types of analysis such as including avalanche problems from the public bulletins in the analysis. More importantly, once the dataset grows large enough, research will be able to include the four new technical MIN reports which were introduced during the winter of 2015/16.

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