TRACKING HELI-SKI GUIDES TO UNDERSTAND DECISION MAKING IN AVALANCHE TERRAIN

Jordy Hendrikx[1*], Christopher Shelly[2] and Jerry Johnson[3, 1]

[1] Snow and Avalanche Laboratory, Department of Earth Sciences, Montana State University
[2] Majestic Heli Ski, Alaska
[3] Political Science, Montana State University

ABSTRACT: Heli-ski guiding can be considered a prime example of high stress, high consequence decision making in avalanche terrain. The combination of factors that make heli-skiing an exciting experience and high value industry create a high pressure scenario that demands consistently high quality decisions. Heli-ski operations provide a unique setting in which to examine the decision making of terrain usage of highly experienced professionals as they balance repurposed terrain, changing hazard ratings, group expertise and, a variety of other factors. Furthermore, given the recent fatalities in the heli-ski industry in Alaska, and the proposed new checks by the Alaska Occupational Safety and Health, there is also a strong desire to better understand, and quantify practices in this industry.

Previous work examining decision making in heli-ski operations has considered case studies of accidents, or close calls. However, no analysis has been undertaken to examine real-time, terrain focused, decision making outcomes as evidenced by ski tracks. Our work will present the first such results having GPS tracked and analyzed 18 days of heli-ski guiding at Majestic Heli-Ski in South Central Alaska. Our results show that when repeatedly used terrain was examined, that there was a statistically significant difference in terrain usage under different avalanche hazard conditions. This analysis highlights that the extreme values (i.e. the 90th, 95th and 100th percentiles) for slope angle, may provide more insight into terrain decisions than considering changes in the entire distribution for a given day due to the mobility of a heli-ski guide. We propose that this methodology to perform real-time tracking and report the terrain based metrics, could be useful if operationalized in real-time for operational self-checking, transfer of institutional knowledge, and external auditing. We compare these findings to decision making in self-powered back country settings which highlights that decision making is about small scale thinking about the immediate landscape in both cases, but that heli-ski guides have more options to move into adjacent areas to aid mitigation.

KEYWORDS: Decision making, Heli-skiing, terrain analysis, GPS.

1. INTRODUCTION & BACKGROUND

Many avalanche accidents are the result of flaws somewhere in the decision process. For back-country skiers and riders the decision of whether or how to navigate potentially hazardous avalanche prone terrain is a mix of snowpack conditions, group communication, limits of acceptable risk and, consequence. While sometimes complex, these small group decisions are typically “self contained” in terms of responsibility and outcome. Now, compound these terrain negotiation decisions when weather, crevasse and avalanche hazard, helicopters, remote alpine terrain and client satisfaction are all combined. Given this scenario, heli-ski guiding can be considered a prime example of stressful, high consequence decision making in avalanche terrain. The combination of factors that make heli-skiing an exciting back country (BC) experience and valued industry create a high pressure scenario that demands quality decisions day after day. Heli-ski operations provide a unique setting in which to examine the decision making of terrain usage of highly experienced professionals as they balance repurposed terrain, changing hazard ratings, group expertise and, a variety of other factors. Furthermore, given the recent fatalities in the heli-ski industry in Alaska, and the proposed new checks by the Alaska Occupational Safety and Health (AKOSH) (Garcia, 2014), there is also a strong desire to better understand, and quantify practices in this industry.

Heli-skiing has been an increasingly popular activity since its inception in the 1960s with operators

* *Corresponding author address:*
Jordy Hendrikx, Department of Earth Sciences
Snow and Avalanche Laboratory, Montana State University, Bozeman, MT 59717;
Tel: 406-994-6918;
Email: jordy.hendrikx@montana.edu

now established in most alpine countries around the world (Wanrooy and Anthony, 2006).
Heli-skiing is a well-established industry with British Columbia, Canada having an estimated 90% of the global market share. In Canada the industry accounts for approximately 100,000 skier days with gross revenues exceeding $100 million annually (HeliCat Canada, 2014). Outside of British Colombia, Alaska in the USA now has the highest concentration of heli-ski companies. The industry continues to grow and has seen an increase in the number of providers, with many newer operations starting around the world, including more new operations in Alaska, the Arctic (e.g. Greenland), Central Asia, and the Himalaya.

The Majestic Heli-ski operation was established in 2013 and is based out of Sutton in South Central Alaska. They use a team of six guides, and one Eurocopter A-Star AS-350 B2 Helicopter. Majestic Heli-Ski operates in the Chugach and the Talkeetna Mountain Ranges, with the majority of the time being spent in the Chugach. The operating season is approximately February 15-May 1. No more than fifteen guests are hosted at one time. A typical operating day is eight guests or less, with 2 guides (1 per group of 4). The elevation band skied is typically 2500'-8500' (760m – 2590m). Their tracks, an expression of their terrain usage and decision making, will form the basis of this paper.

The winter of 2014 was well below average for snowfall for the mountains of Alaska. Typical yearly snowfall totals for the region are in excess of 600 inches above 3000' (approx. 15,240 mm above 915m) for the Chugach Mountains. The winter of 2014 was approximately 50% of average within the region. Furthermore, surface hoar, a persistent weak layer often responsible for avalanche activity, was formed in early February and was persistent and reactive throughout the season, right up to the closing day. For Majestic, there were only 6 non-flying days due to inclement weather for the 2014 season, which was low compared to the more typical 20-25 non-flying days that are experienced in the Chugach.

Fundamentally, the goal of the decision making process in avalanche terrain as a heli-ski guide is no different to that when making decisions in non-mechanized backcountry terrain; in all cases skier safety trumps other considerations. However, the process is somewhat more complex given the costs of transport and services, client demands, weather and number of possible locations. As a result, heli-ski guiding is an exemplar of high-pressure decision making, where safe and efficient decisions must be made (Gmoser 1976; Grimsdottir and McClung, 2006). For this reason, we have decided to focus on decision making by heli-skiing guides as an example of real-time professional decision making in avalanche terrain.

The focus of this paper is to examine heli-ski guide travel behavior in avalanche terrain given changes in avalanche hazard, avalanche problem, group demographics, number of days with the same group, and lead guide. Our focus will be on how avalanche hazard is mitigated by use of alternative terrain within their permit area, and how the same (repurposed) terrain is used differently under varying avalanche conditions. Our data comes from Majestic Heli-ski.

2. METHODS

2.1 <u>Data Collection</u>

During the Spring of 2014 heli-ski guides at Majestic Heli-Ski recorded 18 days of travel in avalanche terrain as part of their routine heli-ski operations using a handheld GPS (Garmin Etrex 20). The GPS was simply turned on, and placed in the top pocket of the lead guides pack at the start of each day, and then turned off at the end each day. A simple daily tracklog was recorded for each day and stored on the GPS. The GPS was configured to record the position at the "Most Often" setting, providing the highest spatial resolution tracklog possible with the given device. An analysis of the GPS track showed that this resulted in an average spacing of less than 3m between GPS points that were recorded while skiing. A more in-depth analysis of the positional accuracy of this and other hand held GPS recording devices (e.g. Smartphones) is presented in Hendrikx and Johnson (submitted), and supports the data presented here, indicating that this device is suitable for this application.

The 18 days were recorded between 19 March and 25 April, 2014. The timing of these 18 days were not selected for any predetermined period, and can be considered to be representative of typical snow and avalanche conditions in their area during the normal season, with a wide range of conditions documented.

In addition to the GPS data collected for each day, the following associated information was also documented:

- The general region of operation for the day (i.e. Mountain Range(s))

- Avalanche forecast as determined by the operation (i.e. Low / Moderate / Considerable)
- Client group(s) size
- Client group(s) demographics (i.e. Gender, age and their approx. ability)
- The guide(s) and lead guide for the day.

2.2 Data extraction

Our methods utilized detailed spatial analysis of GPS tracks for each day with topographic and hazard data within a Geographical Information System (GIS). We then combined the associated group and guide data. Our approach presented here is an extension and modification of that presented by Hendrikx et al., (2013), Hendrikx et al., (2014), Hendrikx and Johnson (submitted). The following section will therefore provide only a brief overview of the methods used.

The geospatial GPS data was collected at the end of the period and downloaded from the GPS units into our GIS (ESRI ArcGIS 10.2). These data were then overlain on a 30m digital elevation model (DEM) for the entire area. We then utilized a Python Script developed by Hendrikx et al., (2013) and updated by Hendrikx and Johnson (submitted), within the GIS to extract the key terrain based metrics. These metrics included: Speed, Duration, Slope, Aspect and Elevation.

We then separated the actual skiing terrain usage from the helicopter flight path, as both were recorded by the GPS. We achieved this by filtering the data based on speed of travel (i.e. >50 km/h), and the difference between the GPS elevation (accurate to approx. 50m with the Garmin eTrex) and the ground elevation of the track as calculated within the GIS. Where this elevation difference was greater than 50m, or the speed was less than 50km/h we assumed this to be actual skier usage of the terrain. Following this automated filtering procedure we manually checked the remaining portions of the tracks, to ensure accurate representation of the actual terrain used by skiers. This manual check revealed minor errors (e.g. slow low elevation flight over ridge lines for reconnaissance), that were then manually corrected within the GIS. Using this filtered set of data, which represented only the skiing component of the GPS tracklog, we then summarized the terrain based metrics for each day. These summary metrics from the terrain were then used for analysis with the avalanche conditions, group and guide based data.

2.3 Data Analysis

Due to the size of the collected data set (n=18 tracks), we consider this an example of an extended case study and so statistical robustness in our data should not be expected, nor implied. Despite this limitation, we did want to explore if there were any statistical trends evident in this data.

Statistical description and analysis of the combined data set was completed in StatSoft Statistica 12. The terrain metrics for each day were plotted and the differences between similar groups (e.g. Days with same hazard rating) were statistically assessed using the non-parametric Kolmogorov-Smirnov two-sample test (Conover, 1999). Our analysis examines the data at two scales. First, we consider the data for all 18 days, representing 183 skier days with between 6- 10 runs per day, to investigate changes in overall decision making outcomes using four variables that vary over time and space: avalanche hazard ratings, avalanche problem management, terrain choices made by the lead guide and, how terrain use changed over the course of several days with the same group. The reasons for doing so are to investigate the decision making over the course of the block of days of skiing to determine how operational decisions shift according to conditions. The goal is to understand how heli-ski operations adapt to changing conditions over time and so reduce risk to clients.

We also examined the use of terrain within small geographic areas (i.e. repurposed individual ski runs), under different avalanche hazard conditions to understand how slight adjustment in negotiating the same terrain is used on different days to account for varying avalanche hazard. Heli-ski operations enjoy considerable flexibility with respect to the use of terrain and we would expect guides to alter their plan to ski in a specific location by changing the flight path or landing zone in order to place the group in less hazardous conditions. The goal of this examination is to understand how guides adapt their terrain use at a fine scale.

3. RESULTS

3.1 Terrain metrics for all days, over the entire area

How did the guides adjust their terrain usage with respect to their organization's assessment of the avalanche forecast, hazard, guide, and skier group? We might expect to see lower slope angles, or different aspects preferentially used under higher hazard conditions or identified hazard. We might also expect to see some variation between the choices of lead guides. Finally, we also investigated changes in terrain usage as guides skied with the same group over time to examine issues related to McCammon's (2004) familiarity heuristic; a condition where decision makers embrace past experience as a way to avoid risk. We found little evidence for all of these expectations. When we group the terrain metrics by avalanche hazard (low, moderate, considerable), or avalanche problem (persistent slab, warming), or lead guide (1,2, 3), or number of days skiing (1-5) we do not observe any statistically meaningful difference between the slopes or aspects as indicated by the GPS tracks. This suggests that changes in terrain metrics, when grouped, may vary due to other reasons or just random variation, with these groupings providing no statistically significant explanatory power. However, when we consider all the data for individual days, independent of their respective groups, we can find some weak statistical differences, but only for aspect. For example, the 10th of April is statistically different to the 1st of April with respect to the aspects used. This can be observed in figure 1.

Another way to consider these data is rather than consider the whole data set for each day (i.e. a record of the entire day of skiing), to focus only on the steepest terrain used on a given day. When we consider the maximum slope angle and the 95th percentile of slope angles (i.e. 5% of the time slopes steeper than this were used), then we can see some minor differences. On low hazard days, the average maximum slope was 37.7° and the average 95th percentile was 28.8°. Compare this to 39.0° and 29.4° for moderate hazard days, and 36.0° and 24.3° for considerable hazard days. These differences in percentiles are statistically significant for the 95th percentile values between considerable and moderate hazard (p value = 0.03), but due to the small sample size, we have limited confidence in this result. With a larger sample, we may see further evidence that the 95th percentile and possibly maximum slopes used decrease at the higher avalanche hazards (e.g. considerable). These results provide evidence that, as expected, guides make explicit adjustments to slope angle with respect to hazard.

3.2 <u>Terrain metrics for two days, in the same area</u>

The second approach to the data analysis was to examine fine scale tracks of terrain use within a small geographic area that has repeat use (i.e. same general ski runs with slight variation in terrain usage), under different avalanche hazard and avalanche problems. Figure 2 shows the GPS

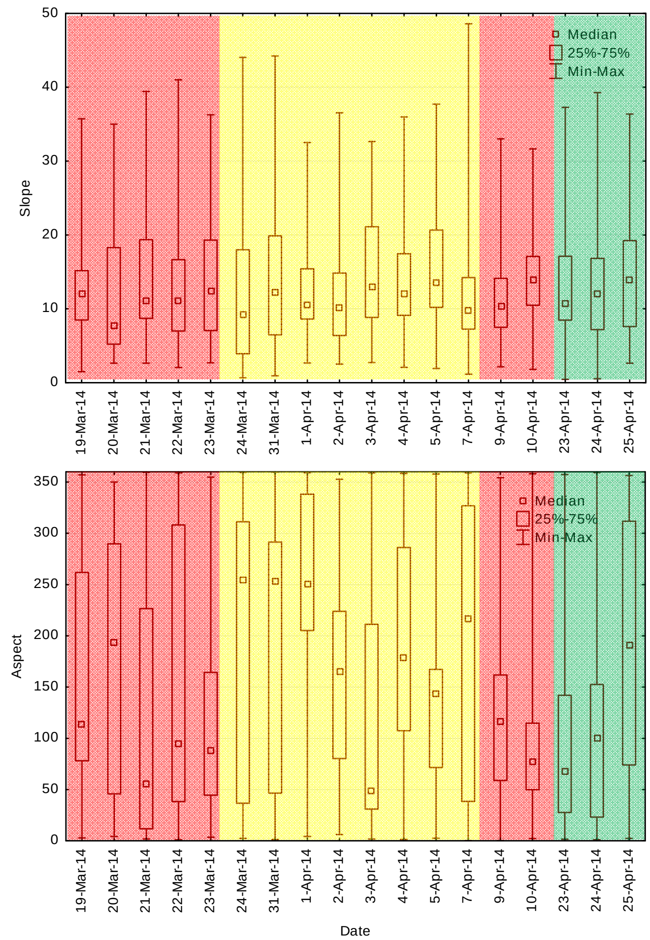

Figure 1: A box and whisker plot showing the minimum, maximum, median and interquartile range, for slope angle (top plot) and aspect in degrees from north (bottom plot) for each of the 18 days of the study. Color shading represents the avalanche forecast on the day, with red for considerable, yellow for moderate and green for low

tracks for two days (April 9th and April 23rd) within the same small, approx. 1km by 2km basin. The avalanche hazard on the first day (April 9th) shown with the orange diamonds, was considerable and wind slab and persistent slab were identified as the main avalanche problems. The avalanche hazard on the second day (April 23rd) shown with the green circles, was low, and wind slab and warming were identified as the main avalanche problems. The same lead guide was responsible for terrain choice on both days and group ability was similar. Figure 2 also shows an inset graph with the frequency histogram of slope

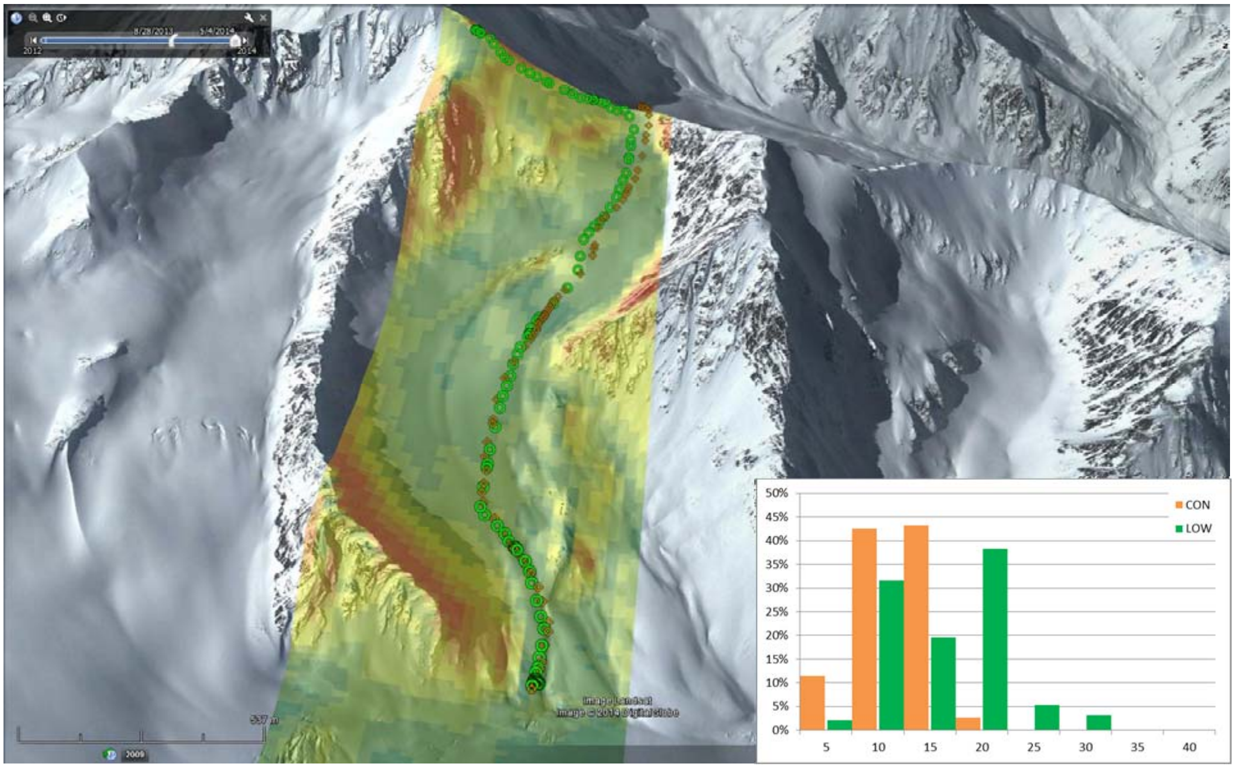

Figure 2: GPS tracks for April 9th shown with the orange diamonds (Considerable avalanche Hazard / Wind slab and persistent slab) and April 23rd shown with the green circles (Low avalanche hazard / Wind slab and warming), overlain on a 30m slope map (where red is steep and green is lower angled), overlain on Google Earth. Inset graph shows the frequency histogram of slope angles for the two tracks, with the April 9th track shown in orange and April 23rd track shown in green.

angles for the two tracks, with the April 9th track shown in orange and April 23rd track shown in green. The non-parametric Kolmogorov-Smirnov two-sample test (Conover, 1999) reveals that the slope use on these two days in this same basin were statistically very different ($p < 0.001$ level). On the low hazard day the groups skied markedly steeper terrain.

4. DISCUSSION

The analysis clearly shows that when we combine the terrain metrics from each track, for each full day of skiing, into groups as defined by (1) The avalanche hazard, (2) The avalanche problem, (3) The lead guide, or (4) the number of days skiing with a group, we do not observe any strong statistically significant differences between the slopes or aspects used by these different groups (Figure 1). At first this may seem surprising. For example, is there really no difference in terrain usage by a lead guide on a low hazard day, compared with a considerable hazard day? One might assume that there would be, and experience suggests that there is, however these differences are not clearly evident when the data is grouped, and when the entire day of skiing is considered. In contrast, when individual days are considered, we can observe differences between some days, with respect to the aspects used, but not the slope angles.

In part this result is understandable, due to the metrics selected being only slope and aspect. Depending on the nature of the avalanche problem, one can mitigate the avalanche hazard on a given day, and maintain relatively steep angles, by moving to other (e.g. less loaded / less solar) aspects. Furthermore, in the case of a heli-ski operation, they can also easily move to other areas within their permit areas, where the instability may be shallower and more easily managed, or possibly nonexistent. Therefore, one of the clear advantages in a heli-ski setting, where rapid re-positioning is possible, is that the avalanche hazard can be mitigated in this way. This suggests that the metrics used here to describe the terrain usage, when presented for a whole day, and then grouped, are likely over-simplistic to describe terrain management practices for a highly mobile operation like heli-skiing. Additional parameters that describe the terrain (e.g. Concavity, convexity, distance to valley or ridgeline) may help, but are still likely to suffer from the same issues when grouped.

However, when we consider the cases where the same terrain is used (i.e. repurposed) within the same small basin but under different avalanche conditions, we can see some interesting features (Figures 2). Notably, approximately 70% of the tracks on both days are very similar – i.e. the component of each track in the lower angled, safe terrain in the valley. Only the entry point for the run and uppermost parts of the tracks are different. On the considerable hazard day (April 9th) the entry point was on a saddle exhibiting very conservative ski terrain; no slopes steeper than 18° were skied. By contrast on the low hazard day, the entry was higher on the ridge, and a steeper 29° roll over was skied. The analysis of the terrain metrics in this case study of two tracks (Figure 2) indicates a clear difference in the slopes used. If we consider this case, we can observe that the most extreme slope angles of the day show the greatest difference, with maximum slopes of 18° and 29° for the considerable and low day respectively, whereas the mean (while still statistically significant) only varied from 9.2° to 13.8° respectively. However, it should be noted that the additional slope angle is sufficient to place a ski party at risk from avalanche. Therefore, we propose that rather than focus on the entire population of slope and aspect data for each day, we should be more focused on the most extreme (or steepest) component of a day – i.e. the maximum, 95th and 90th percentiles of the slopes used, to show potential changes in travel behavior under varying conditions. These are also the most likely trigger points for avalanches, as these slopes are typically in the start zones.

Despite some of the limitations of this method, when applied to a mobile heli-skiing setting, we propose that if this analysis were automated and summary terrain metrics provided in near real-time (e.g. at the end of a day) that objective and unbiased assessment of the days terrain usage could be performed by an operation. These metrics or summaries of these metrics (e.g. maximum slope, 95th and 90th percentile) could then be plotted for each day, and for each guide etc., to document and check for potential terrain creep or potentially hazardous behavior by one or more guides. This process would also aid a heli-ski company that wanted to catalogue their repeat terrain and assist in developing rules and guidelines for usage of that terrain, or as a teaching tool for senior guides to pass knowledge about terrain selection to newer guides. It may also play a useful role for educating clients on how and why guides select terrain over the course of several days, or for auditing operational activities by external entities like Occupational Safety and Health.

We can extrapolate these findings to self-powered backcountry skiing where rapid transport to mitigate terrain hazard is less straightforward – i.e. it is much harder to move 30km west into a new mountain range once problems are encountered. Often, in discussions of terrain usage, the conversation is framed as scale independent, however we demonstrate here that considerations of scale and the ability to move within a wide area are both important hazard mitigation strategies. Avalanche hazard forecasts and resultant problems are, by necessity, applied to large landscapes. This analysis reminds us that safe travel is perhaps as often a game of small scale thinking about the immediate landscape. The resulting changes in decision making to ensure safe travel at the smaller, basin scale are measurable and quantifiable. This analysis provides a useful case study and quantification of the terrain selection behavior of professional heli-ski guide as they take into account both large spatial scale and small spatial scale problems.

5. CONCLUSIONS

Using handheld GPS devices, we successfully recorded the terrain usage data, and associate demographic, avalanche and group information for 18 days of client guiding by heli-ski guides at Majestic Heli-Ski in Alaska. When we group metrics of these terrain data by avalanche hazard, avalanche problem, lead guide, or number of days skiing with a given group, we did not observe any statistically meaningful difference between the slopes or aspects as indicated by the GPS tracks. We attributed this to both the simple terrain metrics, and also the ability of a heli-ski guide to move to more favorable areas, with better stability, and thereby maintain steeper, and often more sought after slope angles. However, when individual tracks in repurposed terrain were examined, we noticed a statistically significant difference in terrain usage under different avalanche hazard conditions. This highlighted that the extreme values (i.e. the 90th, 95th and 100th percentiles) for slope angle, may provide more insight into terrain decisions than considering changes in the entire distribution for a given day. We propose that this methodology to perform real-time tracking and report the terrain based metrics, could be useful if operationalized in real-time for operational self-checking, transfer of institutional knowledge, and external auditing. We compare these findings to decision making in self-powered back country settings. This highlights that decision making is about small scale thinking about the immediate landscape in both cases, but that heli-ski guides have more options to move into adjacent areas to aid mitigation.

6. ACKNOWLEDGEMENTS

We would like to thank the guides at Majestic Heli-Ski for their willingness to participate in this study and have their every move tracked and analyzed

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