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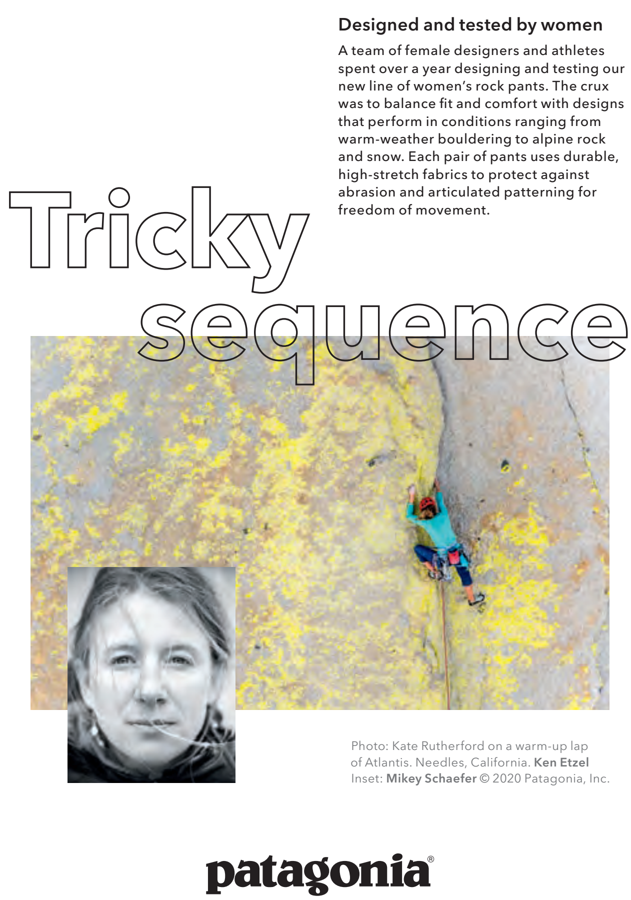

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Photo: Kate Rutherford on a warm-up lap of Atlantis. Needles, California. Ken Etzel
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the avalanche journal

Contact *The Avalanche Journal* editor: editor@avalancheassociation.ca
Return undeliverable Canadian addresses, change of address and subscription orders to: Canadian Avalanche Association PO Box 2759, Revelstoke BC V0E 2S0 Email: info@avalancheassociation.ca
Publications Mail Agreement No. 40830518 Indexed in the Canadian Periodical Index ISSN 1929-1043

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CONTENTS
SPRING 2021

COVER MELISSA SAARINEN
CONTENTS DANYELLE MAGNAN

in this **issue**

Walter Bruns
CAA President

CAA President's Message

LOOKING TOWARDS THE AGM

AS YOU MAY HAVE GATHERED from the increasing frequency of member newsletters, the CAA's annual general meeting and spring conference is fast approaching. Depending on where you live or work, spring is either just around the corner or it has already sprung! I hope you had a good winter season, all things considered, and hope to 'see' you at our Virtual Spring Conference and AGM.

As we will report in more detail in May, the CAA has had a good year considering the global circumstances our industry finds itself in. A big thank you goes out to everyone who sought or maintained membership, to all the students who continued their avalanche education, and to all the subscribers that stuck with InfoEx. Thanks also to our dedicated staff who adapted admirably and managed the association effectively.

I'd like to write a few words (again) regarding our professional path towards competency-based membership. This daunting project is relentless. Every step is complex and challenging; however, we can't take short cuts. There have been unintended consequences and even collateral damage, but we remain committed to the path.

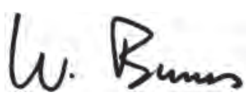
Membership applications are a case in point. To demonstrate or to confirm that one has met or satisfied almost 100 competencies to a given level of proficiency requires considerable effort. The new processes that took effect last summer increased the burden not only on the applicant to complete their application, but also on our membership committee to assess and approve their application. The workload for this group of volunteers became onerous.

The increased effort for applicants from other professions, such as guides, has been described by some as excessive and superfluous. Guides already have professional certification representing a set of related (or even identical) competencies. We are collaborating with technical specialists from the ACMG to develop a schedule of equivalencies between our respective competency profiles so that assessments can be streamlined in future.

Ryan Buhler stepped down as membership committee chair and director in January. Kerry MacDonald has taken on both roles and several members answered the call to join the committee. Thanks to everyone for your commitment and contributions.

While directors Matt MacDonald and Penny Goddard carry on for the second year of their respective terms, seven of us on the board stand for re-election at the AGM. There will have been ample notification and opportunity for other interested candidates to come forward. Your engagement, whether as a volunteer on committees, on the board, or just as a voting member of our organization, is what keeps the CAA strong and effective.

Best wishes,



Walter Bruns, CAA President

Joe Obad
CAA Executive Director

Executive Director's Report

DISPATCH FROM THE BRIAR PATCH

AS I WRITE THIS, we are approaching one year since COVID-19 changed our lives. These changes remain profound, dynamic, and ongoing. Each adaptation seems to be met with new uncertainties in other areas. We continue to seek ways to support members through these challenges, with cautious optimism for next season.

InfoEx subscribers faced a great deal of uncertainty coming into this season that continues to this day. Manager Stuart Smith, with the support of the InfoEx Advisory Committee, has worked with subscribers to offer flexible options for adapting subscriptions to scaled back or delayed operations. In general, subscribers have responded positively to this support.

Staff and the IAC worked with the ACMG on a trial group subscription run that has enhanced the data sharing from independent guides. A review will be conducted prior to establishing this as a permanent InfoEx fixture.

The InfoEx gang continues work on the three-year MAInEx project to add mobile and other functionality to InfoEx to ensure it is there for the next generation of subscribers—both with revised features and improved underlying technology.

The Industry Training Program remains in high demand. Students impacted by last year's cancellations sought to get back on track, while many practitioners took the opportunity for training while regular employment was limited. These and other factors filled the ITP schedule. Hard choices were made to limit courses in person to Alberta and B.C.

In the face of this demand, instructors, staff, and students have faced numerous curveballs this season. ITP Manager Andrea Lustenberger's leadership ensured we were as prepared as possible. For the most part, our systems have proven to be robust and adaptable. B.C. and Alberta have endorsed our courses, allowing them to continue in the public interest as safety training requirements.

This preparation softened the blow of COVID on students, instructors, and host operations. Staff were required to juggle numerous students to address COVID quarantines. In the field, instructors and host operations have adapted to COVID mitigations. Together, this dedication has allowed us to execute courses without cancellation (to date) in a year of high demand.

On the membership front, we are pleased most members renewed. We hope this is a sign those affected by scaled back operations have adapted to other work.

We have entered the era of competency-based membership. This is a long awaited milestone, and members have much to be proud of, but achieving this strategic goal comes with challenges. Below I endeavour to be transparent about where we have dropped the ball.

The new competency-based Active and Professional membership application processes were adopted following member review and endorsement of new bylaw changes at the 2020 AGM. The revised process is structured around new practitioners who build workplace portfolios over time. We did not anticipate the rush of applications from highly experienced guides. Many of these applicants typically work in the mechanized backcountry sector and were seeking work for which CAA membership is required.

The process to date lacks efficient means to recognize training or certification gained through well-established credible organizations. We are working with the ACMG to map their training and certifications against the workplace portfolio of our process right now. Ideally, we can move from mapping competencies to providing certain classes of ACMG members efficient tools for their applications. To be clear, this process will not be a free pass for anyone, but a more efficient method of demonstrating commonly proven competencies from a known organization.

This challenge occurred against a backdrop of substantial change: a flood of applications racing in at season start, a change in Membership Committee leadership, several new members joining the committee, staff changes, and a couple more kitchen sinks I have likely forgotten.

We responded to these changes with several joint staff and committee training sessions. We've engaged a Professional Member to provide initial basic application reviews to help the committee get off to a strong start. With folks up to speed, we have addressed most of the backlog of applications.

Looming in the background is simplification of the application process. With all of our processes we run into the theme that members want a high degree of confidence in their fellow members and believe in the competency-based approach. Delivering an application system that addresses competence across all domains but does not overwhelm applicants with complexity is a work in progress. Nevertheless, it is a ball in the briar patch we're going to get our hands on to get this game back on course.

This edition of *The Avalanche Journal* likely reaches you just prior to the spring meetings, which will be online again this year from May 3–7. The CAA staff and I look forward to engaging with you on these and other issues. Until then, we wish you the best with the conclusion of your season.

Joe Obad, CAA Executive Director

Alex Cooper
Managing Editor

From the Editor

UNDER PRESSURE

BACK IN EARLY JANUARY, I was fortunate to take (and pass) the Avalanche Operations Level 1 course. For seven long days, 17 of us learned about snow, avalanches, weather, how to dig a profile, and how to tell the difference between decomposing precipitation particles, facets, and rounds. James Blench, Jock Richardson, and Chris Dyck were our instructors and they each brought a distinct teaching style to the course. Over the course of the week, I realized what a privilege it is to spend time with such a team.

My goal going into the course was to get a better appreciation for avalanche work; if I'm going to be editing a magazine on the industry, it's important to at least get a taste of what the work is. I also wondered how it might change my approach to the backcountry. I feel I've got a pretty good track record there, but I know I've gotten away with mistakes, and there are likely times I've gotten away with mistakes that I don't even know I made.

In regards to the first goal, I gained a newfound appreciation for a former roommate who works up at Rogers Pass and has to dig to ground semi-regularly. But I also gained an even greater appreciation of the nuances that go into forecasting (not that I thought it was easy before). The most nerve-wracking part of the course for me was filling on the PM worksheet at the end of the day six. I felt palpably nervous as I assessed the conditions based on what we observed that day. All the little things I missed, the observations I didn't note went through my mind. What if I got it wrong? My report had no consequences, but I did get a sense of pressure that forecasters are under every day.

Did it change my approach to the backcountry? So far I don't have an answer. I know backcountry recreation is a world of lifelong learning, and my inclination is that this is one step along the way. My mindset has become more conservative over the years and my patience has increased.

***

While editing this issue, I was surprised at the amount of content in it. There's always a moment in the process where I panic because I'm not sure if I lined up enough articles, or I'm worried someone won't come through. Slowly but surely articles trickled in and it all came together. Thank you to everyone who contributed and met my deadlines.

This issue covers a variety of topics, some that you may be familiar from last year's Virtual Spring Conference and Virtual Snow Science Workshop. A few stem from poster presentations at VSSW that I felt deserved more attention. I hope reading those articles will refresh your memory or spark a renewed interest in those topics.

I am grateful for all the contributors, but especially Adam Campbell and Kevin Hjertaas. Their story—the death of Adam's wife Laura Kosakoski in an avalanche last winter—has been widely reported. In this issue they share their respective healing journeys. Both were difficult to read and I am very appreciative of their willingness to open up here. I hope their accounts provide guidance to others dealing with trauma.

***

The spring issue has hopefully arrived in your mailbox before the Virtual Spring Conference. I've only been to one Spring Conference since taking over *The Avalanche Journal*, but I do miss it. As much as I enjoy watching the case study presentations from the comfort of my living room, the lack of networking opportunities definitely hurts the ability to find content for the magazine. That's why I hope you will reach out and let me what's going on the industry. Do you have a story to tell? Do you know of a story to tell? Are you aware of some new research that you think is of interest to members? Is there a case study you'd like to know more about? Please email me at acooper@avalancheassociation.ca.

Alex Cooper

CAA Welcomes **New Staff**

Rosie Denton
Rosie Denton is our new Membership Services Coordinator. She's excited to be part of such an important organization, learn more about the avalanche industry, and work with the rest of the CAA team. She brings experience in customer service, marketing, and event management, and spent five years working at Selkirk Tangiers Heli Skiing. Her other background is in fundraising with non-profits. She loves to be in out in the garden and is a director with the Revelstoke Local Food Initiative. When not exercising her green thumb, you'll find her mountain biking or skiing.

Roberta Saglietti
Roberta Saglietti is new the Office Administrator at the CAA. Roberta spent 16 years working in investment banking in Europe before moving to Canada. When she's not in the office, you can find her out hiking, cross-country skiing, or casting her fishing rod into local lakes and rivers. She's new to the winter backcountry, but is excited to learn more about the Canadian avalanche industry, and we're excited to have her customer service and organizational skills onboard.

Sarah German
Sarah German has joined the CAA in the role of ITP Course Logistics and Support. Prior to this, she was a partner in Amiskwi Lodge for 12 years and helped with the logistics of building and running a backcountry lodge. She has 15 years experience in the staffing industry, recruiting and managing workforces in remote location. She also volunteered at the 2010 and 2014 Winter Olympics. Sarah loves skiing and enjoying the mountains and the ocean as much as possible, and feels fortunate to be part of the CAA.

LEFT TO RIGHT: ROSIE, ROBERTA AND SARAH. // PERSONAL COLLECTIONS

Fuse News

Rupert Wedgwood and Dave Cochrane

DURING THE EXPLOSIVE Advisory Committee's February conference call, we reviewed explosive incidents that were reported this winter on InfoEx. From an industry-wide perspective, the majority of incidents seem to be associated with human error rather than product failure. The sage opinion of committee veterans is that over the past 15 years the frequency of reported incidents has been on a downward trajectory. In the long view, this is a good news story for the regulators, product developers, practitioners, educators, and the CAA.

When accidents happen, particularly those involving explosives, they have industry-wide consequences. Looking back over the past 30 years, we can recall this occurring with the recoilless rifle program in the early '90s, several Avalauncher events during the first 15 years of the millennium, and several times when fuses and pull-wire ignitors were brought into scrutiny. Several of these events had tragic consequences, devastating families and scarring communities. Most resulted in stop-work orders while the incidents were investigated and solutions brought forward. The causal factors often included human error, product failures, and sometimes both.

Yet, how reliable are memories alone to support industry wide trends when it comes to safety? The famed behavioural economist Daniel Kahneman brings to light many thinking traps associated with sample size and human fallibility in his *New York Times* bestseller, *Thinking, Fast and Slow*.

The popular "Swiss Cheese" risk management model is a helpful visualization of the avalanche industry's collective and ongoing best efforts to reduce the likelihood and severity of accidents. When they do occur, regulators, manufactures, educators, and practitioners have worked together to scrutinize and amend our systems, techniques, education programs, and procedures to reduce the likelihood of repeats. The CAA's Avalanche Control Blasting course and the Explosive Advisory Committee were brought in to existence to help reduce the likelihood and damage near misses and accidents can cause.

InfoEx is an ideal location to inform each other of explosive related issues. It adds to our Swiss Cheese model by providing an early warning system to practitioners.

Effective risk management depends crucially on establishing a reporting culture. The practice of good record keeping in all areas of our explosives programs enables us to investigate causal factors more objectively. Serious issues must be brought to the attention of program managers, manufacturers, regulators, and on occasions the RCMP. Each operation needs to have explosive procedures and operational plans that address issues covering storage, transportation, use, and destruction of explosives. It's not just the bosses we report to who have obligations to workplace safety; the chain of accountability and ownership spans from the grizzled veteran to the first year technician. We each have a responsibility to ensure we don't excede our scope of practice or step away from our operational procedures, and that we are applying our Avalanche Safety Plans diligently.

> **Effective risk management depends crucially on establishing a reporting culture.**

The CAA Strategic Plan emphasizes education and proficiency as a means of enhancing our professionalism. To this end, the CAA's Board of Directors and staff, with support of the Membership Committee, have been working at developing a means of helping members look more closely at their competency spectrum and proficiency. These competencies are equivalent to skills of our trade that will develop both in breadth and proficiency over our careers.

Different sectors of the avalanche industry will demand greater proficiency in some competency domains than others. As we move between sectors or shift roles within our current one, our proficiency may decline in some competencies while it develops in others. Those currently applying for memberships are the first to be exposed to this new approach. For those of us who use explosives or validate the induction of new staff into these practices, the highest level of vigilance is required to ensure we have and maintain the appropriate competency profile and proficiency for the scope of practice we endorse or undertake.

There are many roles and tasks that facilitate the safe development of proficiency. The blasting course is both a good entry level course and competency refresher; like a box of liquorice all-sorts, there's something there for everyone. There is no substitute for good in-house training and mentored development, where the incremental exposure to new competencies can lead to greater responsibility and leadership roles as proficiencies are developed and mastered.

Although near misses need to be minimised, when they do occur they offer valuable insight into where, how, and why our safety systems have been stretched to near failure. Having a workplace environment and culture where these can be debriefed in a collegial and professional manner using the language of human behavioural fallibility and latent program flaws is beneficial. Failures and near misses can be turned into success stories by updating procedures and training programs to maintain quality assurance with these findings. Sharing these innovations and accounts is an excellent grassroots way of helping our community further the shared goal of greater workplace safety and professionalism.

Below are some anecdotes to help illustrate human errors resulting from operational pressures and training shortfalls.

A couple of years ago myself (Dave Cochrane) and another guide were conducting a helicopter control mission in a heli-skiing venue. We planned the route and discussed the usual targets. We prepared three bombs and had three more bags of ANFO ready, with boosters primed in a wooden box ready to insert into the bags after we used the first three bombs. The bombardier wore a harness and was secured with a rope lanyard and prussik to two points in the helicopter.

When the double-primed booster was placed in the ANFO, we sealed the bag tightly with a nylon/plastic quick tie. Once we had the appropriate communication with the pilot, we approached the target and followed the same protocol of commands each time: request to open the door, open it, prepare the charge, ignite it, and drop it on the target.

Unbeknownst to the bombardier, when he fastened the quick-tie to the charge and tightened it, he somehow captured the lanyard tightly within the quick tie. After the fuses were lit, he could not lift the bomb and realized it was attached to the lanyard.

I was spotting from the co-pilot seat and heard an unusual exclamation and was asked if I had a knife that I could pass back quickly. I could not get my knife right away as it was in my hip pocket. Next, I heard through the headset that everything was OK as fuse cutters had already done the job. The bomb was jettisoned immediately right on target and we proceeded to the next targets. My knife is now easily accessible in my chest pocket.

We were both experienced blasters and had not seen this happen before. It obviously highlighted for us the necessity to always follow every step of the process with an intense visual double-check of each detail. Errors do happen and checks and double-checks are vital.

Were we pushing hard to get the work done quickly? I don't think so, but it cannot be denied in the past we have had pressure. There is always some heli-stress from noise, speed, cost, fear of making a mistake, and other factors.

A second example is when an experienced guide joined our crew at our heli-skiing lodge for a few weeks. While planning for a control mission our fellow guide expressed interest in gaining experience in all aspects of the control program. We learned the guide had limited training and we agreed to give him as much training as we could.

The guide participated in the planning and preparation. To help gain familiarity with lighting fuses, we cut a couple fuses into short lengths without the blasting caps and demonstrated how to place and hold the pull-wire igniter so it would not slip off the fuse when lighting. After placing and pulling a dozen igniters with successful ignition, we discussed and reinforced the importance of holding the pull-wire correctly.

We continued teaching and coaching safety protocols and proceeded on our first mission together. The guide was coached to be bombardier with an experienced blaster present. While proceeding through the mission, quite a few of the ignitors were poorly placed and pulled off the fuses without successful ignition. It was an excellent learning experience and easy to fix without any danger or interrupting the mission.

During our debriefing the guide expressed his self-imposed pressure to perform. He felt a day or so of reflection on the training and more practice with igniters would have been helpful. He did not fully understand that when an igniter is pulled off the fuse it is easily corrected. This input helped to revise and improve training for better understanding and confidence.

Explosives are an important tool for many avalanche professionals and require a high degree of technical competence. As Canada embraces the use of remote avalanche control devices, new and unanticipated events are likely to occur, while our collective experiences grow along with our best practices. By continuing to adhere to our industry's safe work practices, following our operational procedures, and working in a collegial manner with explosives regulators, we will continue to set ourselves up for success into the future.

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Contributors

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18 SHOULD WE JUDGE DANGER OR SAFETY IN AVALANCHE TERRAIN?
32 TERRAIN USE AS A LENS FOR UNDERSTANDING DECISION MAKING IN AVALANCHE TERRAIN

MATTHEW STEPHENSEN is a doctoral fellow in cognitive psychology at UiT The Arctic University of Norway. He works with the Center for Avalanche Research and Education (CARE) examining the cognitive processes that shape risk perception.
18 SHOULD WE JUDGE DANGER OR SAFETY IN AVALANCHE TERRAIN?

THOR VEEN has a background in biological sciences and is fascinated by the mountains. He loves to apply technology to better understand the natural world. Using drones to study snowpack characteristics and avalanches is a dream combination merging professional and personal passions.
27 MONITORING AVALANCHE HAZARDS USING REMOTELY PILOTED AERIAL SYSTEMS

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20 RADAR TRAPS FOR AVALANCHES—THE BEAR PASS SYSTEM

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43 CULTURES OF RISK MANAGEMENT

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16 BE HUMBLE TO YOUR EGO

front lines

20

RADAR TRAPS FOR AVALANCHES—THE BEAR PASS SYSTEM

in this **section**

// GRANT GUNDERSON

Be Humble to Your Ego

SUBJECTIVITY IS BAKED INTO FORECASTING OBJECTIVE OUTCOMES

Lee Green

WHAT IS EGO? We inevitably smuggle ego and human factors into our daily forecasts and discussions of avalanches. There is no escaping it unless we stay ahead of ourselves by accepting where our failures might be. If we understand our weaknesses, we can game how we're wired, learn from our errors, and help prevent catastrophic loss.

The word "ego" can be thrown around loosely, and may take on a negative connotation when heard in epithets such as "Captain Ego." However, ego directly translated from Latin is "I," which is an ownership we all have a claim to. Freud tried to define ego as part of a mediative device between the ID and Superego, initially using it to define one's sense of self and believing we were driven to act by it. Aristotle believed our true selves are reflected through our acts, decisions, and beliefs. Buddhism tries to define one's identity in five heaps, teaching that we can tame or disregard our ego's impulses.

So, why does this matter when it comes to avalanches? It matters because avalanches do not fail because of ego, nor do they have a sense of self. However, we do fail and we have a sense of self. Our intellectual diversity highlights how subjectively we paint the world around us. After many hours of morning meetings, working with many different characters, debating what we "felt" like the snow was doing, I've been intrigued with how much personal baggage we pack into each meeting with us.

As an example, I've been completely wrong forecasting the hazard and still doubled down on my assumptions because of a previous time when conditions looked similar. In fact, arguing or debating what we each think is happening with the snow is so common, it's just part of an average meeting. I personally take great pride in my objectivity, but on introspection I realize that pride is at odds with objectivity every time. Even knowing this intimately, I fall victim to the human phenomenon regularly.

In their paper, *The Human Factors Analysis and Classification System–HFACS,* published in 2000, Scott Shappell and Douglas Wiegmann showed human error had been implicated in 70–80 percent of all civil and military aviation accidents. An example was Asiana Flight 214 in which the pilots, by misjudging their approach, crashed the plane. The incident resulted in 200 injuries and three fatalities. Further investigation showed human error was a key contributing factor. Since then, much research and development has gone into automating flight where the data shows that human failure can be offset by small systematic measures.

In the 1990 book *Human Error,* James Reason notes that, "You cannot change the human condition, but you can change the conditions in which humans work." The aviation industry has accepted that the exposure to the hazards of flying multi-million-dollar machines at high speeds in the atmosphere creates too unacceptable of a risk to be left to predictable human error.

Arguably every incident in the five volumes of *Avalanche Accidents in Canada* has an element of human error in it. The FACETS acronym sheds light on this: a known mountain area where changing conditions are taken for granted; insecurity or a feeling to impress an employer; a commitment to a skiing objective or operational agenda; deferring to a more experienced person; FOMO (fear of missing out); or just the plain old need to look like a rock star.

When we introduce more variables and larger consequences to our decision making, we actually perform worse at objectivity, not better. As explained in Anuj K Shah and Daniel M Oppenheimer's 2008 article, *Heuristics made easy: An effort-reduction framework,* cognitive overload requires us to resort to our heuristics and biases as there is too much stimulus for us to sort through and create an objectively correct output. Given that we have been shown to fail predictably when overwhelmed with stimulus, we have to find a way to outsmart ourselves by accepting our shortcomings in order to correct for them.

One way to outsmart our humanity is to take the subjectivity out of uncertainty wherever we can. Tools we use daily can help with this. *The Conceptual Model of Avalanche Hazard* is not just the basis of a workflow on InfoEx, it's an algorithm that helps us compartmentalize the complex decisions we have to make and turn them into bite-sized chunks more suitable for digestion. Instead of the cognitive burden of deciphering what you mean by "spooky," there are defined terms and definitions to explain that sentiment, helping eliminate any possible miscommunications. By embracing this framework, we not only enforce a common language, we simplify our decision making by building a robust methodology that can be criticized easily. We actually *want* to be criticized easily here, because the possible outcomes to our decisions can result in damage to infrastructure, catastrophic loss, and/or death.

If we allow our egos to be smuggled into our decisions for *any* given selfish reason by replacing these devices with our own subjectivity, we are not only opening ourselves to error, we are also doing others a disservice by creating a harder problem for them to solve. We remove the information they are expecting to receive, replace it with our personal sense of self/ego, and assume they perceive the problem as we do.

It's possible they may perceive the problem as we do, but they may not. Given the weight of consequence, is it worth leaving that to chance? If there are tools or devices available to address any point of possible miscommunication, it is our responsibility to use them. Communicating hazard in the mountains is challenging enough before complicating it with a myriad of possible human factors. As professionals we need to consider the consequences of our human input daily.

Ego is innately stuck with us. Regardless of how we may view its intangibility, it has taken a considerable amount of time and human effort to try to understand it. Hopefully we can continue to build uniformity in the dynamic conditions in which we work and, where it does exist, we should all truly embrace it.

Semantics, defined jargon, and simplified repetitive approaches are important as they create objectivity. We're all wrong at some point, and the more experience we gain in the mountains, the more likely we will stumble upon our own error. Experience isn't learning how not to fail; it's learning how to fail more gracefully. So instead of relying on the kindness of confirmation bias, we should all strive to accept that we are confined to our human limitations and make corrections for them whenever we can. We should embrace the fact that until we evolve into a species that can fully grasp the wicked problem that is avalanches, we should stay humble in anticipation.

Should We Judge Danger or Safety in Avalanche Terrain?

Matthew B Stephensen, Markus Landrø, Jordy Hendrikx

MINDY AND KELSEY HIKE UP THE VALLEY, weaving their way through thinning forest and steepening terrain to the top of a small rise where they stop. They are entering avalanche terrain and it is time to decide if they should continue on their planned route. Ahead of them is a long, steep climb up a broad face to reach the more gradual ridgeline that they intend to follow to the summit. They dig a snow pit but do not find any sign of the persistent weak layer mentioned in the regional avalanche forecast. The snowfall has been light but steady and the winds variable over the past 48 hours. Although no cornices are visible on the ridgeline, spindrift indicates the wind is starting to pick up. They have not seen any obvious avalanche clues. They stand there, pondering the uncertainty of the conditions.

Kelsey breaks the silence: "It looks good. I don't believe it's dangerous," she remarks. "I think we should continue."

Mindy wrinkles her brow: "Really? It doesn't look safe to me," she counters. "We should turn back."

Why might two recreationists with similar training, competency, and experience make opposite decisions when judging the same evidence about the conditions? To try to answer that question, we must consider the cognitive mechanisms involved in the decision making process.

QUESTION FRAMING

When we judge risk, we are judging the attribute of an object, action, or situation. Attributes are commonly understood in terms of their multiple dimensions. For example, the attribute 'speed' is often understood in terms of two dimensions: fast and slow. Those two dimensions are like two sides of a coin, distinct but indivisible. They provide opposing but complementary perspectives.

We tend to focus on a single dimension when making a judgment. For example, when judging speed, we commonly ask, "Is it *fast*?" or alternatively, "Is it *slow*?" rather than formulating a judgment using both dimensions. It is a natural process of language and thought to frame judgments with only one qualitative dimension of the judged attribute.

Similarly, when moving through avalanche terrain, we might also use a single qualitative dimension to frame avalanche risk judgements such as "How *safe* are the conditions?" or "How *dangerous* are the conditions?"

What we wanted to know is: does the choice of frame have an effect on perceived risk and behavioural decisions? If so, can we strategically employ that frame to increase the likelihood of more cautious, conservative judgments and decisions in avalanche terrain?

Our research found that frames influence perceived avalanche risk and behaviour intention. In a series of studies, we examined how backcountry skiers judged hypothetical scenarios of skiing in avalanche terrain (presented in the form of a photo and basic regional avalanche advisory information) when asked to judge *safety* or *danger*. We found that risk judgments framed in terms of safety (*"How safe is it?"*) resulted in more cautious, conservative judgments and a lower likelihood of skiing than judgments framed in terms of danger (*"How dangerous is it?"*).

This happens because the frames "safe" or "dangerous" direct the decision maker's attention during the judgement process. Judging *"How safe is it?"* defines *safe* as the reference point for the risk judgment. This focuses attention on finding and evaluating evidence of safety. Under conditions of uncertainty when there is no definitive indication of safety, such as in our example with Mindy and Kelsey, safety is judged as lower due to the lack of supporting evidence. Lower safety implies the unspecified opposite dimension—higher danger—resulting in a lower likelihood of deciding to ski a slope.

Conversely, when judging the danger (*"How dangerous is it?"*) of the same scenarios, danger is judged to be lower (and consequently safety is perceived to be higher) because of the lack of definitive evidence of danger, resulting in a higher likelihood of deciding to ski a slope.

By asking backcountry travellers to judge how safe the conditions are, we exploit the lack of definitive evidence of safety to actually promote more cautious judgements and behaviour. Failing to find evidence of danger should not be considered an indication of safety. Yet failing to find evidence of safety must be considered an indication that it is not safe.

STRATEGICALLY FRAMING RISK PERCEPTION IN AVALANCHE TERRAIN

Decision making in avalanche terrain is seldom free of uncertainty. How we formulate risk judgments can have a real impact on how people perceive risk and, ultimately, when and how they decide to act. How then might we harness the power of framing in the avalanche industry?

The use of framing to promote specific judgments and decisions is an established practice in fields such as media and marketing. We can similarly employ framing to promote safer risk perceptions and behaviour in avalanche terrain. Guides, avalanche warning services, and avalanche safety educators have substantial control over the phrasing of questions about the risks they assess for a backcountry trip.

Framing can be systematically applied to numerous risk judgments and decisions, whether it be deciding to ski a specific line or deciding to open or close specific terrain.

Communication between members of a group travelling in avalanche terrain could be positively impacted by increased awareness of the framing effect. How information and questions are framed could influence other group members' perceptions of the current risk and the decisions made or communicated between members of the group. For example, when a guide or group leader notices changes in the conditions, they can advantageously frame their question to the group to focus attention on those changes in relation to the basis for any earlier judgments of safety.

Let's say the basis for the decision to ascend a slope is that the old snowpack is stable with fresh, non-wind loaded powder snow on top. After some climbing, the snow surface shows signs of wind effect. Focusing on establishing safety forces the group to reassess the conditions relative to the previous evidence of safety (non-wind affected snow) and the possibility that conditions have changed (evidence of wind slabs). The group must evaluate if the evidence previously indicating safety is no longer present or if new evidence of safety is available. The group must therefore reconsider its arguments and possibly change its decision.

Asking *"How safe is this slope?"* increases attention paid towards evidence of safety—not just the absence of signs of danger—making the group more critically aware of any changes in conditions while guiding the decision toward a more conservative, transparent, and possibly safer outcome.

Framing risk judgments alone is insufficient to ensure safer behaviour among all backcountry recreationists. It is no substitute for the training, knowledge, and experience to understand and apply information about the conditions. Nonetheless, adopting a strategy for framing risk judgments can increase the likelihood of more cautious, conservative behaviour.

There is often so much uncertainty when making decisions in avalanche terrain that we must utilize any tool or method that can help, even if just a little. Critically, one wants to minimize the chance that a "*go*" decision is made under objectively "*no-go*" conditions. If the way a question is framed influences the decision of whether to ride or not, then avalanche risk management strategies, tools, and education should recognize and account for this effect and incorporate framing risk judgments into routine practices to reduce the potential for avalanche accidents.

The next time there is uncertainty about the current avalanche conditions, stop and think about the way you frame the question, and how it could influence your decision. Think about how you might be able to harness framing to provide that extra margin of safety in times of uncertainty.

A peer-reviewed article that provides a detailed account of our research on question framing is forthcoming in the *Journal of Experimental Psychology: Applied*. That article can be accessed at doi.org/10.1037/xap0000354.

Radar Traps For Avalanches –the Bear Pass System

Susanne Wahlen and Lorenz Meier

Editor's note: The authors of this article are employees of Geoprævent AG, which developed the Bear Pass radar avalanche detection system. This article is presented because I believe it is of interest to CAA members. It does not indicate an endorsement of Geoprævent.

MORE THAN 2,000 AVALANCHES IN 16 MONTHS

Since November 2019, avalanche radar systems at two critical locations have been monitoring Highway 37A to Stewart, B.C., around the clock, in all weather conditions for the Ministry of Transportation and Infrastructure (MoTI). The radars permanently scan the slopes for avalanches, detecting events of different sizes in real-time and automatically notifying the local avalanche professionals. The data gained from this innovative technology provides significant support for avalanche risk management, including timely notifications that help the team improve their forecasts, shorten response times, and reduce highway closures in general.

REDUCE CLOSURE, INCREASE SAFETY

Highway 37A is the only road in and out of Stewart. The coastal town is the northernmost ice-free port in Canada and an import and export terminal. The inland connection, Highway 37A, leads over avalanche-prone Bear Pass to Terrace via Meziadin Junction. A total of 72 active avalanche paths threaten the road on both sides, with avalanches affecting the highway between November and May due to natural and planned events. Avalanche management includes preventative closures and targeted avalanche control. Nevertheless, the route is expected to stay open and safe for residential and commercial traffic as much as possible.

Previously, monitoring options for the avalanche team were limited to on-site observation during daylight and good weather. Using the automatic avalanche detection system (AADS), avalanche activity monitoring is now possible around the clock, in all weather conditions, via computer or cellphone. An online map displays all detected avalanches and is supplemented with important event parameters, such as duration, front speed, and size. In daylight, a series of event images is recorded and displayed online. While monitoring avalanches is now conveniently possible from the office, the avalanche radars have to withstand the harshest conditions—and function reliably at all times.

RADAR TRAPS

Why use radar? Radio waves can penetrate weather phenomena such as fog, clouds, rain, and snowfall, and can detect objects at relatively long distances. Unlike other remote sensing technologies that use shorter wavelengths (e.g. lasers), radio waves are absorbed less by the medium they pass through, making it possible to achieve long ranges. This is why radar technology is particularly suitable for reliable, remote, and all-weather applications such as the detection of aircraft, ships, or spacecraft.

The radar applied for avalanche detection takes advantage of the Doppler effect by detecting the frequency shifts caused by moving objects. Doppler radars are best known for detecting speeding vehicles on roads, but they can also detect a snow or ice mass moving down a mountain slope. Special algorithms recognize the signature of an avalanche in the radar signal and track its course as it moves downslope. We use Doppler radars with large antenna opening angles of 90 degrees horizontally and 30 degrees vertically. This allows us to cover large areas and several avalanche paths with a single device. Currently, our avalanche radars have a range of five kilometres for reliable avalanche detection.

For the pilot project at Bear Pass, two sites were chosen:

1. George Copper for the northern slopes of Mt. Gladstone, about halfway between Meziadin Junction and Stewart; and
2. Little Bears for the eastern slopes of Mt. Shorty Stevenson, about 15 kilometres from Stewart.

The monitoring area at George Copper includes six avalanche paths and a small hanging glacier, while the Little Bears monitoring area stretches over four avalanche paths. Various simulations of the radar coverage and

FIG. 1: AUTOMATIC AVALANCHE MAPPING ON THE ONLINE DATA PORTAL.

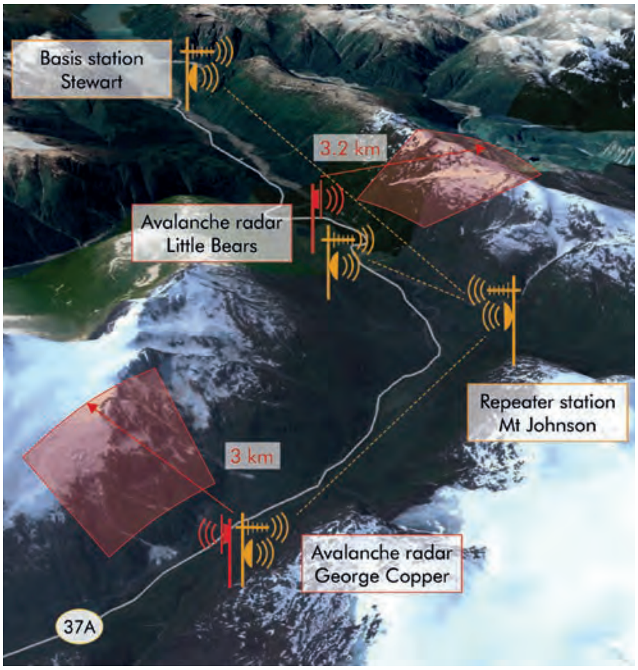


FIG. 2: AADS SYSTEM SETUP AT BEAR PASS (GOOGLE EARTH).

visibility revealed the best locations for the two desired areas of interest. Other considerations that went into the site evaluation were exposure to natural hazards such as avalanches and rock fall, accessibility, power supply, and communication options.

CHALLENGING SYSTEM DESIGN

The AADS at Bear Pass is the most remote system Geoprævent has completed so far. There is neither electricity nor mobile phone coverage for data communication, and fully autonomous operation of the stations is required for the duration of the entire winter season. Additionally, the radar stations have to function under several metres of snow and in harsh coastal weather conditions. We tailored the system to the local requirements and optimized it with energy-efficient components and settings.

A sophisticated combination of fuel cells and solar panels ensures reliable power supply, with the fuel cell taking over when solar power is not available. This setup ensures power during poor weather and periods when the station is in the shade of the mountain, as is the case for George Copper between November and February. The fuel cell uses hydrogen from methanol as a carrier to generate clean and efficient electricity. To ensure air supply during large snow accumulations, the fuel cell is equipped with a four metre snorkel that also acts as an exhaust pipe for CO2. Water generated in the reaction is drained from the cabinet through a built-in conduit in the concrete foundation. Several tanks of methanol with automatic switches are stored in the cabinets, which is sufficient for the entire winter season.

An additional challenge we faced was communication to the stations. Neither avalanche radar site has direct line-of-sight to the base station in Stewart. For this reason, we designed communications via an elevated repeater station on Mt. Johnson. The station is housed inside an 8.5-metre-high rocket-shaped enclosure, and equipped with three south-facing solar panels and an integrated fuel cell. The radar stations transmit detection data, high-resolution images, and system-relevant status reports over two different communication channels (for redundancy) via Mt. Johnson to Stewart, where they are uploaded to Geoprævent servers from the MoTI base station.

The Mt. Johnson repeater is the hub of the entire system. In addition to data transmission, it enables remote access to the stations for our team. We permanently monitor the functionality of all our systems worldwide with automated health checks and notifications in case of irregularities. This enables us to identify potential problems at an early stage and solve most of them without on-site intervention.

SNOW-FREE RADAR

Contrary to the assumption that a radar is a large, spinning device, the radar head—the heart of the AADS—is a laptop-sized device that weighs only a few kilograms. The operating conditions, with heavy winds, snow cover, and freezing temperatures, are challenging, and conventional equipment would likely fail. However, it is precisely under these conditions that avalanches often occur. This is why we developed a bespoke anti-snow system that automatically detects and removes snow accumulations from the radar head.

The AADS also includes an event camera with 42 megapixels resolution. Upon motion detection, the radar triggers the camera to record a series of images. In daylight,

FIG. 3: AADS SYSTEM SETUP AT BEAR PASS.

FIG. 4: AVALANCHE CONTROL AT THE GEORGE COPPER SITE VIEWED FROM THE RADAR SITE—ONE OF THE RATHER RARE GOOD WEATHER IMAGES.

the camera also captures regular images, allowing remote analysis of the snowpack and detailed inspection using the zoom function. The system automatically reports the detected avalanches, including key data, via SMS or email. The avalanche team in Stewart can log into the online data portal at any time and view the transmitted avalanche data and images. A new feature will make it possible to manually trigger an image of the current situation.

FREEZING FINGERS

System development took place in late summer 2019 and was relatively short considering installation was planned before winter. After successful testing in Switzerland, we shipped the components to Stewart. At Bear Pass, Axis Mountain Technical prepared the sites, built the foundation, and set the poles. Once our two engineers arrived for the installation in early November 2019, we thought the cold and wet weather would only be a temporary phenomenon. However, the weather set in for the next 10 days and the onset of snowfall led to some freezing fingers during installation.

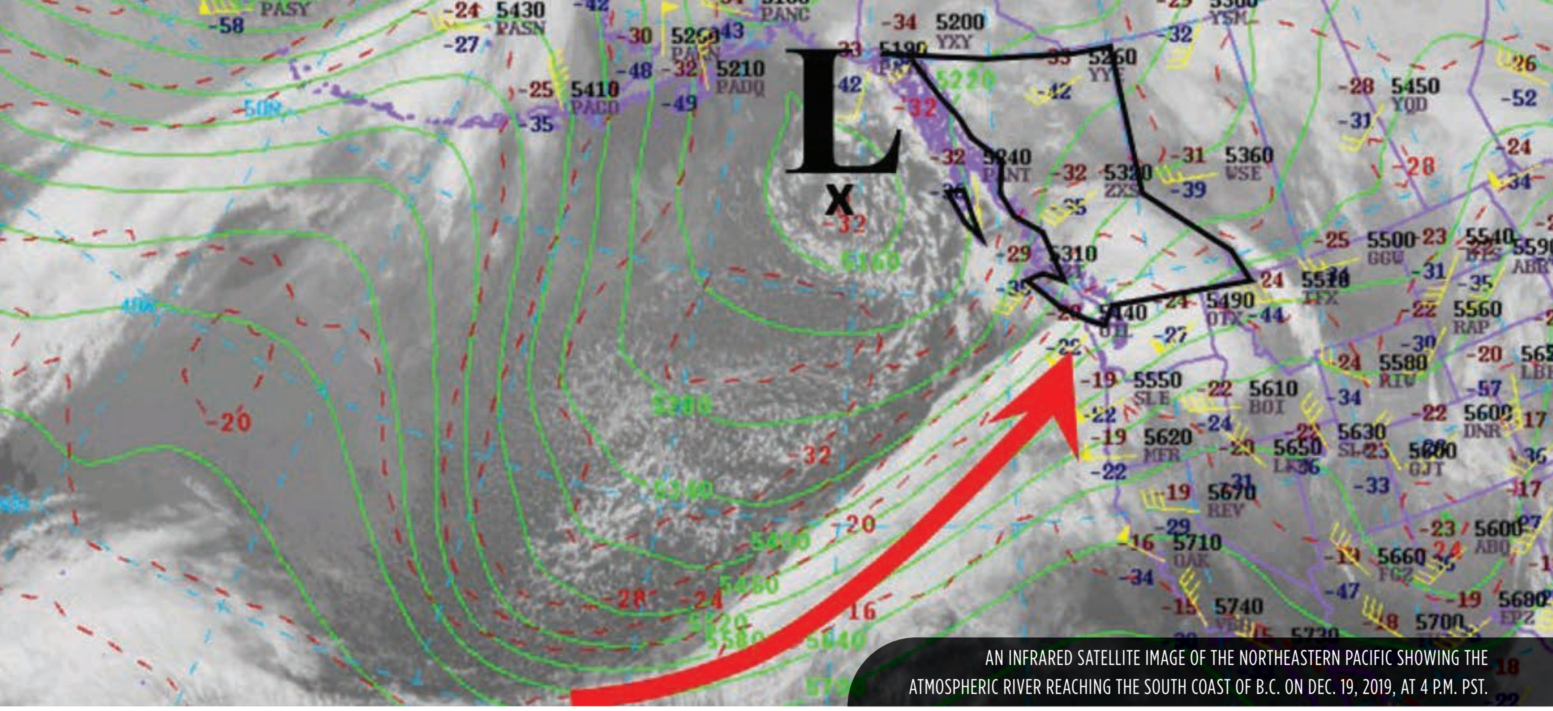
Axis Mountain Technical assisted us in installing the radar sites at Little Bears and George Copper, the repeater site on Mt. Johnson, and the base station in Stewart. Since the three mountain sites were only accessible by helicopter, the installation schedule was further limited by weather and required several adjustments to the schedule. Despite the unpleasant weather conditions (electronics and humidity do not go together well), we were able to complete the overall system on time, as planned.

THE SIXTH SENSE

The first avalanches at George Copper were detected during installation, which enabled us to test the system with real events. The first winter of operation, 2019-20, was characterized by above average snowfall and the two radar stations detected more than 1,200 avalanche events—722 at George Copper and 385 at Little Bears. More than half of the events at both sites occurred in the dark, and 37% at George Copper and 47% at Little Bears took place in poor visibility (i.e. fog, snowfall or rain). Only 11% of events at George Copper and 2% for Little Bears were visible. In other words, almost 90% (and even more for Little Bears) of avalanche events would have been impossible or difficult to detect by eye at the time of the event.

Without the system, many events would have been inaccurately recorded. For example, if multiple avalanches occurred overnight in the same runout zone, they could be recorded as a single avalanche. Moreover, smaller avalanches at higher altitudes would not be recorded at all because they are not visible from the road. The AADS provides considerable support in assessing the current avalanche situation and enables the avalanche team to better understand the regional avalanche conditions. As a result, the team was able to verify the accuracy of their forecasts and significantly reduce closure times of the highway by more than 40% compared to the annual average of 88 hours per season over the previous 35 winters.

We would like to thank everyone involved in making this project a success, especially the Ministry of Transportation and Infrastructure, PBX Engineering, and Axis Mountain Technical.



AN INFRARED SATELLITE IMAGE OF THE NORTHEASTERN PACIFIC SHOWING THE ATMOSPHERIC RIVER REACHING THE SOUTH COAST OF B.C. ON DEC. 19, 2019, AT 4 P.M. PST.

Rivers in the Sky

Matt MacDonald[1] & Paul Harwood[2]

SOME OF THE BIGGEST SNOWFALLS in western Canada occur when powerful, moisture-laden atmospheric flows from the subtropics lock onto the west coast for a period ranging from 24 to 72 hours. When landfall is preceded by entrenched Arctic air, the result is copious amounts of snow, often in excess of one metre. Previously known as "Pineapple Expresses," these fire hoses of heavy precipitation are now referred to as atmospheric rivers (ARs) by the meteorological community.

ARs cause significant impacts, including flooding, landslides, and snow avalanches. Recent research has yielded new forecasting resources with impressive accuracy as early as six or seven days out (Figure 1). This article reviews an AR from the 2019-20 winter, focusing on how forecasts performed and what tools are available for AR forecasts and intensity scales.

THE SOLSTICE AR FORECAST

Rewinding our thoughts back to the beginning of the 2019-20 winter, as we approached the winter solstice forecast models, both deterministic and ensembles, were hinting at a very heavy precipitation event some four to five days ahead of expected landfall (see Figures 1 and 2). It's not at all uncommon for any weather model to paint giant bullseyes of precipitation during the west coast's storm season. More unusual and impressive was the consistent signal for very heavy precipitation (150-200mm over 36 hours) from models as the event approached, with only slight shifts in the axis of the moisture plume. From six days out, models aimed the core of the AR at the Oregon-Washington border. As landfall drew closer, the target shifted north to Howe Sound before it settled on the North Cascades. Despite the wavering target, successive model runs showed remarkable consistency with both the timing and intensity of the solstice AR, factors that enhance a forecaster's confidence.

Meteorologists from both the Meteorological Service of Canada (MSC) and the National Weather Service issued early notifications to decision makers some five days in advance of landfall. Following the initial alerts, updates followed via briefings to emergency managers, public facing warnings, media interviews, and posts to social media channels. Working closely with MSC, Avalanche Canada forecasters elevated the avalanche danger across a large swath of mountains spanning from the South Coast all the way through to the South and Central Rockies (Figure 4).

Given their subtropical origins, ARs not only deliver heavy moisture, but ample heat as well. The main uncertainty surrounding the 2019 winter solstice AR was the ultimate peak of freezing levels across the North Cascades, including the Mount Baker ski resort (top lift reaches 1,550m), Allison Pass along BC Highway 3 (1,342m elevation), and the Coquihalla Highway (1,220m elevation). Forecast peak freezing levels varied from as high as 1,700m from the Canadian Global Deterministic System (GDPS) to as low as 1,100m from the cold-biased American Global Forecast System (GFS).

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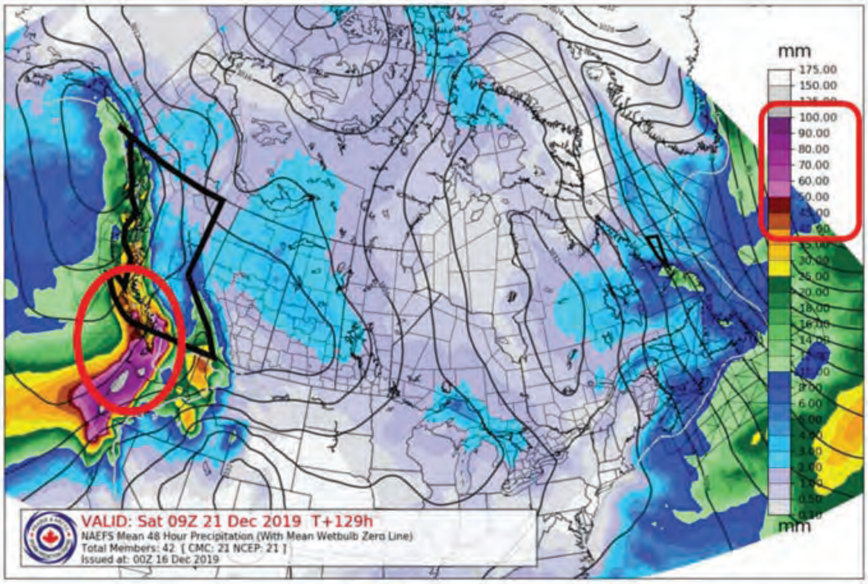

FIG. 1: A 129 HOUR FORECAST OF THE TOTAL 48 HOUR PRECIPITATION ISSUED BY THE NORTH AMERICAN ENSEMBLE FORECAST SYSTEM (NAEFS) ON DEC. 15, 2019, AT 4 P.M. PST.

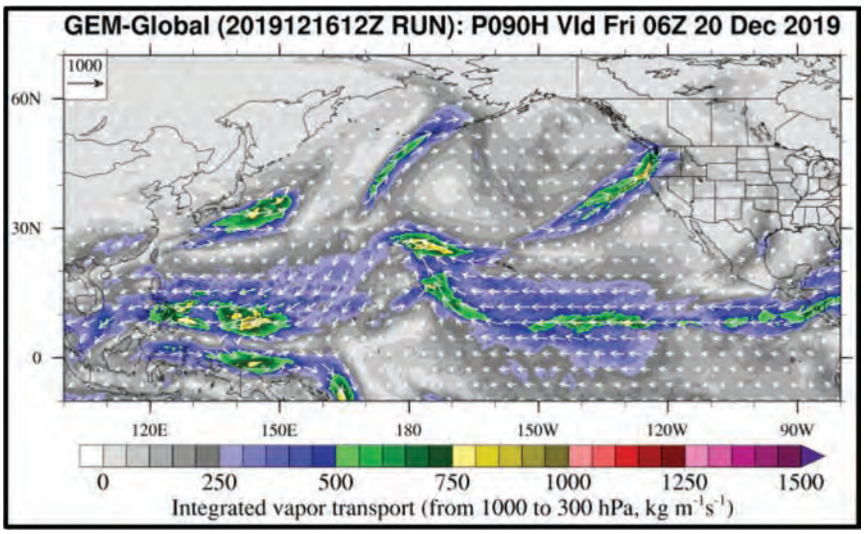

FIG. 2: A 90 HOUR FORECAST OF INTEGRATED WATER VAPOUR TRANSPORT ISSUED ON DEC. 16, 2019, AT 4 A.M. PST BY THE CANADIAN GLOBAL DETERMINSTIC PREDICTION SYSTEM (GDPS).

DIABATIC COOLING

With increased resolution and enhanced microphysical schemes, weather models have significantly improved in recent decades. Fortunately, forecasters' pattern recognition skills, knowledge of local effects, and interpretation of numerical weather prediction have also kept pace. In terms of mountain meteorology, one key improvement has been the theorized and documented thermal effects associated with high precipitation rates. At the onset of falling rain or snow, the precipitation often evaporates or sublimates as it enters drier air below. The phase change of evaporation (liquid water to vapour) or sublimation (ice crystal to vapour) robs the surrounding environment of heat, resulting in a net cooling effect. When precipitation rates are high enough, as with ARs, this diabatic cooling can be strong enough to change rain into snow. Pronounced diabatic cooling can lower snow levels by 200–400 metres, resulting in heavy snowfall and busting cold rain forecasts for the non-astute meteorologist.

During the 2010 Winter Olympic Games in Vancouver and Whistler, the diabatic cooling theory was tested and fine-tuned by lead forecaster Trevor Smith, aka "Diabatic Dude," a regular contributor and co-creator of the Avalanche Canada Mountain Weather Forecast. Applying diabatic cooling adjustments to the models, MSC forecasters can now accurately forecast snow as opposed to rain at pass elevations of the North Cascades. (Admittedly though, not enough snow…)

WITH A 24 HOUR SNOWFALL EXCEEDING ONE METRE ON BC HIGHWAY 3 OVER ALLISON PASS, VEHICLES BECAME STUCK, INCREASING THEIR EXPOSURE TO AVALANCHE HAZARD. NOTE THE SIZE ONE AVALANCHE ADJACENT TO THE TRUCK.

THE SOLSTICE AR

In the end, the solstice AR aligned from the Olympic Peninsula in Washington through the North Cascades and into the South Columbias. It delivered anywhere from 60–130cm of snow, including a new 24-hour snowfall record at Allison Pass of 107cm, with a water equivalent of 68mm. Temperature-wise, freezing levels peaked at 1,200m elevation, resulting in most of the precipitation falling as snow at pass elevations and above. As far as forecasts go, particularly long-range forecasts of atmospheric rivers, this one verified pretty darn well.

While hindsight is often 20/20, despite the early notification to decision makers and highway managers, the impacts to the transportation corridors of the North Cascades were significant. With snowfall rates exceeding 10 centimetres per hour, snowplowing, towing and rescue capabilities ultimately got overwhelmed. The Coquihalla experienced multiple motor vehicle incidents and closures during the storm. In Allison Pass, dozens of vehicles were stuck and stranded as the highway was closed for 47 hours. One person died in an accident near Paulson Bridge on Highway 3 in the West Kootenays. These situations could likely have been avoided, or at least reduced, with better planning and outreach.

This AR had the potential to produce a historic avalanche cycle. Fortunately, the storm came on the heels of the slowest starting winter on record in the North Cascades. There was little snowpack to contribute additional mass to avalanches and the tracks still had significant surface roughness. This limited the size of avalanches and how far they were able to travel. Combined with catchment areas, defense structures, and ditches still being empty, few avalanches were able to reach the highways.

FORECASTING FOR ARS

Recent research has shown both the frequency and intensity of ARs are expected to increase in our changing climate. Fortunately, the accuracy and lead time from AR forecasting tools are also improving and are now readily available to the public. Sources for automated AR forecasts include the Center for Western Weather and Water Extremes (CW3E, https://cw3e.ucsd.edu/). Commentary and probabilistic discussions are also available throughout the winter from MSC forecasters via the Day 5-7 tab of the Avalanche Canada Mountain Weather Forecast (www.avalanche.ca/weather). The tab is updated every Monday afternoon and remains available until Monday at midnight the following week.

In an attempt to better communicate the forecast severity and potential impacts associated with ARs, new classification scales have been developed and proposed by CW3E. A Canadian version has been produced collaboratively by BGC, an applied earth science engineering firm, and Environment and Climate Change Canada. Analogous to the Saffir-Simpson scale for hurricanes, the AR classification scale ranks atmospheric rivers from one to five, with categories described as weak, moderate, strong, extreme, and exceptional.

As with any forecast tool, regular use will help the user gain familiarity and develop a sense of what the associated impacts might look like for their operation or corner of the world. Consider adding the ensemble-based AR forecasts from CW3E to your list of bookmarks. With several days notice from modern atmospheric river forecast models and the accompanying guidance from meteorologists, we can aim to better prepare for these major precipitation events as opposed to chasing our proverbial tails in reactive mode.

Rivers in the Sky. Sounds Lovely. **Now What?**

Paul Harwood

ATMOSPHERIC RIVER FORECASTS are akin to hurricane forecasts in terms of lead time. Instead of reacting to short fuse weather warnings, decision makers have the luxury of several days advanced notification to plan for a potential major event. This luxury still comes with challenges.

This is a snapshot of the BC Ministry of Transportation and Infrastructure North Cascades Avalanche Program's efforts to manage ARs. The program oversees the three major transportation corridors between the Lower Mainland and the rest of the province—Coquihalla Pass (Hwy. 5), the Fraser Canyon (Hwy. 1), and Allison Pass (Hwy. 3).

PLANNING AND COMMUNICATION

Once an AR is forecast, we begin visualizing its characteristics overlaid with the current snowpack. We then have a picture of the anticipated avalanche activity and its timing. With those considerations in mind, operational planning and communication begins.

Leading up to the storm, we confirm all equipment and infrastructure from trucks to weather stations are in good working order. Ensuring catchment areas are clear is a key strategy for reducing highway risk and duration of closures. We make sure we have a strong understanding of our snowpack structure and field trips are made to fill in any knowledge gaps. A strong Cascade snowpack can often absorb a 100–150mm event; however, if deep weakness are likely to awaken, resulting in far running avalanches, stakeholders need to be made aware the possibility of extended closures exists.

This busy preparation phase is a balancing act. If the AR is looking to be a 48–72 hour event, it is essential to give people time off to get some rest. With only four avalanche workers to monitor the three corridors, there are long shifts ahead. Sleeping in trucks and on the office floor is not uncommon during these events.

In highway operations, the avalanche program is just one small component of a giant network keeping the flow of goods and people moving. There is a vast web of agencies that depend on our predictions of how the weather event and avalanche hazard will unfold. Below is a list of partners our program must consider:

- Multiple levels of transportation managers.
- Public highway users through DriveBC and social media.
- Six highway maintenance crews.
- Additional stakeholders and resources we may need to communicate with depending on the anticipated impacts: commercial vehicle inspectors, traffic control personnel, RCMP, BC Ambulance, local SAR, BC Hydro, CN and CP Rail, the local school district, and more.

OPERATIONS DURING AN AR

Here's what we typically do when avalanches are almost certain to hit the highway. First, we monitor remote weather stations, traffic cameras, and several maintenance operators' radio channels to evaluate how conditions are developing. We send avalanche technicians out for onsite assessment and prepare and plan for control work, if possible and necessary.

Ensuring accurate communication is key. We advise maintenance contractors of safe areas to work within closed sections of highway and contact road foremen on adjacent highways to warn them of increased traffic volumes. We message key stakeholders about estimate opening times, double-check the messaging on DriveBC, provide information to media liaisons, and participate in interviews when requested.

Finally, we re-open the highway when hazard levels subside and clean-up is complete.

UNIQUE CHALLENGES

Although 5–7-day lead times are great, the devil is in the details of how the storm eventually materializes and evolves. When contacting the organizations involved in our highway systems, caution needs to be taken that we are not perceived as crying wolf. Uncertainties need to be conveyed and follow-up communication is likely required as the storm gets closer and confidence in the details of the forecast increases. As avalanche professionals, we're familiar with the concepts of uncertainty and probabilistic thinking, but agencies outside our industry are not necessarily as familiar nor as well versed as to their inclusion in operational decisions.

With ARs, there's often a razor thin line between an uneventful rain event and a sustained intense snowstorm that completely overwhelms resources. A slight shift in the storm track and you're no longer the target of the fire hose. The highway passes of the Cascades often find themselves at the critical elevation where a few hundred metres difference in snow level makes for completely different impacts.

In addition to the uncertainty surrounding avalanche forecasts, there are countless factors beyond our control during these intense precipitation events. Unpredictable contributors such as motor vehicle incidents, snow removal machinery break downs, and environmental events like debris flows and flooding all serve to strain operational resources. Even with days to prepare, operational needs and risk assessments require constant updates and modification.

Perhaps a twist on a famous saying captures these challenges: "No plan survives contact with an atmospheric river."

Monitoring Avalanche Hazards **Using Remotely Piloted Aerial Systems**

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Editor's note: The primary authors of this article have a financial stake in the technology presented in this article. It is being published for the interest of CAA members and does not represent an endorsement of their business.

INTRODUCTION

Acquisition of timely, high-strength data is paramount for reliable avalanche hazard forecasting and subsequent risk mitigation. However, acquiring the essential snowpack characteristics is challenging and data acquisition can be time consuming, expensive, and potentially risky. Technological advances in remote sensing have opened up new possibilities to supplement 'boots on the ground' approaches. This ranges from coarse scale monitoring using satellite imagery to finer scale data acquisition using remotely piloted aerial systems (RPAS, commonly known as drones).

This article summarizes our findings of a research project testing the utility of RPAS to assist avalanche risk mitigation for the Ministry of Transportation Snow Avalanche Program (MoTI). We investigated the use of different types of RPAS to conduct visual inspections and assessed the accuracy of snow depth measurements and avalanche deposit volume utilizing structure-from-motion (SfM) photogrammetry. Furthermore, we developed an online data portal to efficiently share the data with MoTI avalanche technicians.

Data collection took place over the course of two winters (2018-2020) and focused on the stretch of Highway 99 along Duffey Lake northeast of Pemberton, B.C. Additional data was collected on Brohm Ridge near Squamish, B.C., and Bear Pass outside Stewart, B.C.

RPAS TYPES AND VISUAL INSPECTIONS

RPAS come in three major categories: multirotor, fixed-wing, and vertical take-off and landing (VTOL). Multirotors consist of three or more rotors mounted on a frame and can hover at points of interest (Figure 1, left). The disadvantage of multirotors is the relatively short battery life, which limits the area that can be covered. Fixed-wings resemble a model airplane and the smaller models are typically hand-launched. The design and lower battery consumption allow for much longer flight times, but they cannot hover in place and require open and flat areas for take-off and landing. The VTOL is a mix between both types: it takes off and lands like a multirotor, but conducts flights like a fixed-wing. The VTOL we tested achieved the transition from vertical to forward flight by rotating the motors from

FIG. 1: TWO EXAMPLES OF RPAS TESTED: A MULTIROTOR (DJI M210, LEFT) AND A VTOL (QUANTUM SYSTEMS TRINITY F90+, RIGHT).

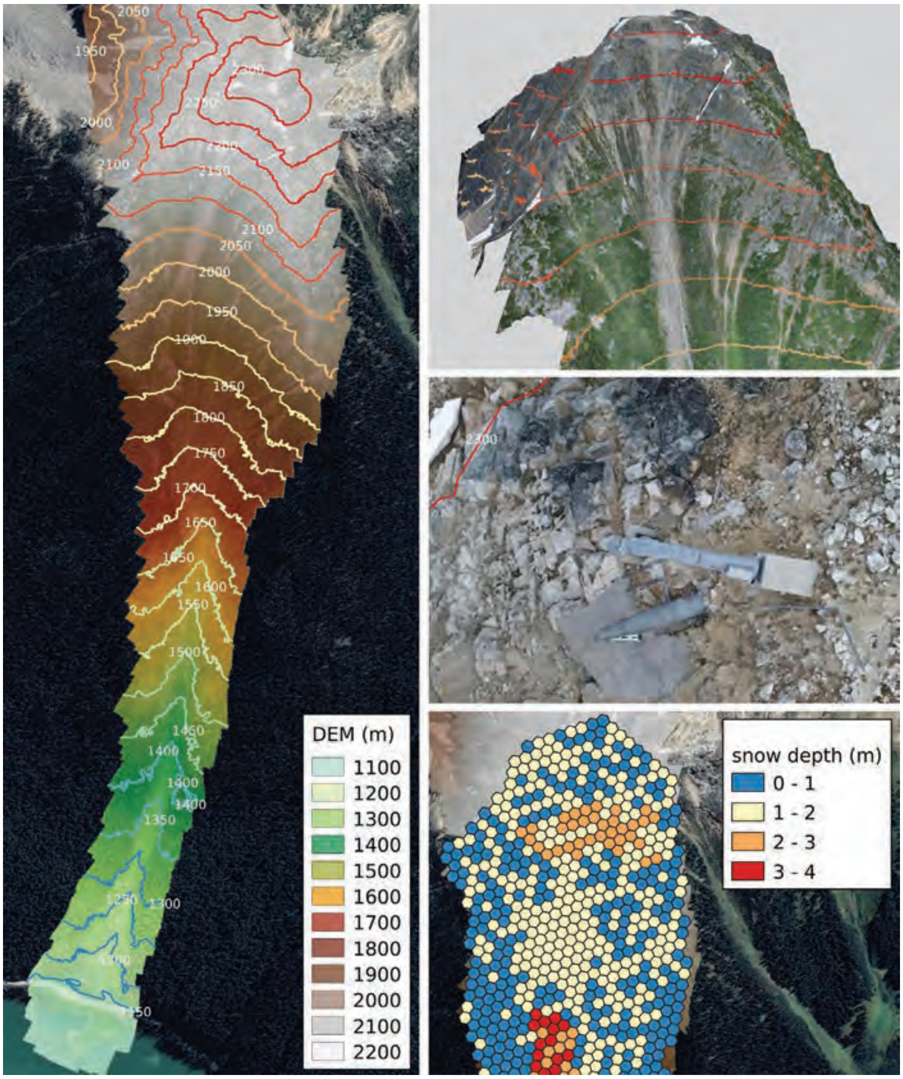

FIG. 2: AN RPAS- AND PHOTOGRAMMETRY-BASED DIGITAL ELEVATION MODEL (DEM) OF AVALANCHE PATH 51.0 COVERING 1.2 KM VERTICAL DISTANCE AND 2 KM HORIZONTAL DISTANCE (LEFT). A 3D VIEW OF THE ORTHOMOSAIC OF THE TOP OF AVALANCHE PATH 51.0 (TOP RIGHT) WITH A DETAIL OF A GAZEX INSTALLATION TAKEN WITH THE SONY RX1RII FROM 120M (CENTRE RIGHT). AN EXAMPLE OF SNOW DEPTH IN A GRID IS GIVEN IN THE BOTTOM RIGHT PANEL.

vertical to horizontal respectively (Figure 1, right).

We tested the following units. All differ in in flight range, payload, GNSS (Global Navigation Satellite System) hardware, and price.

Multirotors:

- DJI M210 with the Zenmuse XS4
- DJI Inspire with the Zenmuse X3
- DJI Mavic 2 Pro with fixed 20 megapixel RGB camera
- DJI Phantom 4 with fixed 20 megapixel RGB camera

Fixed-wing:

- Sense_y Ebee Classic with the S.O.D.A camera

VTOL:

- Quantum Systems Trinity F90+ with the Sony RX1RII.

Flying RPAS in winter conditions is challenging. The cold negatively affects battery life and lithium polymer batteries need to be kept warm to provide sufficient power. Self-heating 'smart' batteries are available for some models and are strongly recommended. Weather conditions can influence the utility of RPAS. Weather resistance varies between models and as a rule of thumb they should only be deployed with wind speeds less than 36 km/h, no precipitation, and temperatures warmer than -10 C. Furthermore, manual flying is very challenging in the cold as fine motor skills are needed for the control sticks. Although thin gloves can be used, pre-planned flights using mission planning software are recommended, with the pilot ready at all times to take control.

During data acquisition, we found multirotors were easy to fly and could be directed closer to the terrain for inspection purposes and mapping. However, flight time was limited and only smaller areas could be covered. For our main study site on the Duffey, avalanche path 51.0, we could only cover the top 300m of the 1,170m altitude range of the entire path.

Our fixed-wing experience was limited as the eBee crashed during its first deployment, presumably due to problems with the mission planning software. This highlights the importance of high-quality software and reference maps on which flights are planned.

With the VTOL we were able to cover the entirety of avalanche path 51.0 from 1,140m to 2,310m in a single one-hour flight (Figure 2, right). Take-off and landing was possible in a relatively small open space (10m by 10m), but a higher flight elevation was required to accommodate the large turning radius.

The quality of aerial images is crucial for the utility of RPAS for monitoring and is influenced by several factors. Foremost is the camera. All cameras tested performed well but the Sony RX1RII stood out in terms of contrast, noise, and dynamic range. Image quality is strongly influenced by the lens and sensor, the latter being very important to avoid blown-out highlights—areas of pure white with no useful information content.

Secondly, using mission planning software to pre-plan flights improves image acquisition and increases ease-of-use in the field. Specific mission parameters such as area covered, flight altitude, and image overlap can be selected, and the optimal flight plan is calculated by the software. Before takeoff, the flight plan is transferred to the RPAS and executed autonomously, while the personnel on the ground can monitor progress and important real-time information such as location, wind speed, and battery status. For some RPAS the whole flight, including takeoff and landing, is performed without control input from the pilot. This greatly facilitates flying itself and standardizes data collection. Once made and tested in the field, the same mission plan can be used for subsequent flights, which greatly reduces the probability of crashing as a known safe path is followed.

Thirdly, the above-ground flight elevation combined with the sensor size determines the ground sampling distance (GSD; cm/pixel), which theoretically determines the amount of detail visible in the image. Although all sensors had a large number of megapixels, and hence low GSD, there were significant differences in image quality (such as contrast) due to variation in lens and sensor quality. As flying in mountainous terrain with variable terrain features requires a conservative (high) flight elevation and results in variation in GSD, we found that camera quality is an important consideration, especially when surveying large areas.

Lastly, the weather and light conditions can strongly influence the imagery. Poor visibility and flat light reduce contrast and the ability to detect terrain details (Figures 2 and 3).

When taking the above considerations into account, successful visual inspections of the terrain and snow features like cornices and fracture lines can be conducted using RPAS under a range of conditions.

SNOW DEPTH AND AVALANCHE DEBRIS VOLUME

Structure-from-motion photogrammetry is an imaging technique for constructing three-dimensional models on the basis of overlapping images. There are different software packages for photogrammetry; we used Agisoft Metashape. RPAS-based SfM photogrammetry can be used to characterize surface topography of the terrain in high detail. The 3D models are the basis for digital elevation models (DEMs). The accuracy of the 3D models and DEMs strongly depends on the quality of the images and the accuracy of the GNSS receiver on the RPAS. When the receiver is not very accurate, ground control points (GCP) with accurate geographical coordinates can be used to increase the spatial accuracy of the DEMs. A significant disadvantage is that it is time consuming, difficult, and dangerous to deploy GCPs across avalanche areas. This can be partly avoided by using clearly visible and stationary points in the landscape, but these can become covered with snowfall. The best option is the use of real time kinematics (RTK) or post-processing kinematics (PPK). GNSS correction technology allows fast collection of georeferenced images at centimetre-level accuracy, resulting in spatially accurate and high resolution maps.

We estimated snow depth by subtracting DEMs of a snow-free, barren-ground reference from snow covered DEMs. We estimated the accuracy of measuring snow depth through DEM differencing by comparing estimates of xyz position against ground control points. We confirmed that the standard internal GNSS receiver of RPAS have high variance that, if used by itself, would lead to variance in the DEMs up to one metre. Using PPK-based DEMs allowed us to estimate snow depth with an accuracy of around 10 cm, which was verified using manual snow depth measures with a probe.

The scale and resolution of the DEMs open the possibility of remotely estimating snow depth over large areas such as an entire avalanche path (Figure 2) and can similarly be applied to estimating the volume of avalanche deposits. We tested this procedure on a very large avalanche from East Strohn at Bear Pass during the winter of 2020 by conducting

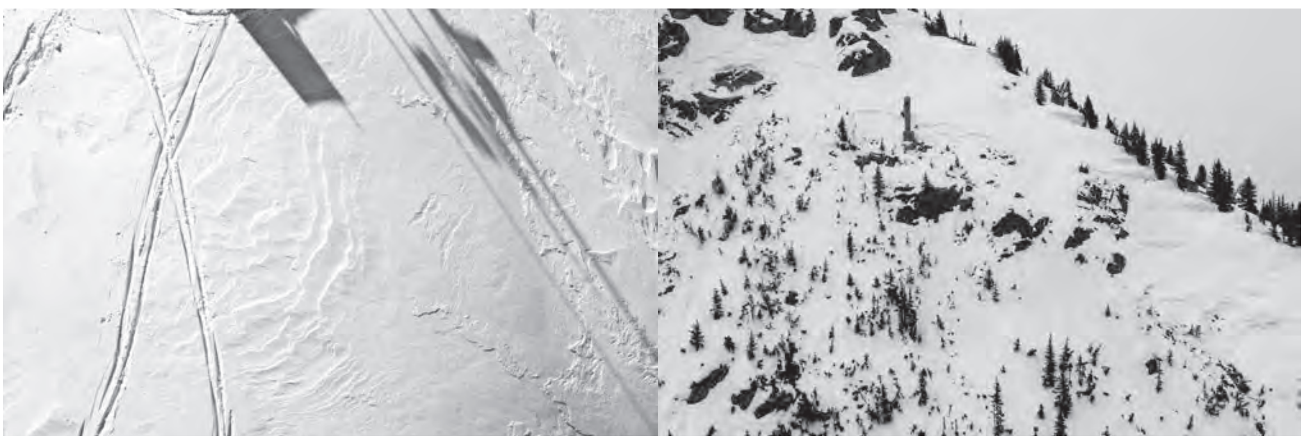

FIG. 1: LEFT: AN EXAMPLE OF A SUNNY, HIGH CONTRAST IMAGE TAKEN AT LOW FLIGHT ELEVATION. RIGHT: AN IMAGE OF A GAZEX INSTALLATION TAKEN DURING AN OVERCAST, LOW CONTRAST DAY. NOTE THE FRACTURE LINE IN THE UPPER PART OF THE IMAGE. BOTH IMAGES WERE TAKEN IN THE UPPER PART OF AVALANCHE PATH 51.0.

an avalanche deposit survey and a subsequent snow-free summer reference survey. Both surveys were conducted using GCPs. We confirmed the size five classification using DEM differencing and the utility of this approach for rapid estimation of avalanche volumes. The volume, combined with estimates of the proportion and density of debris composition—in this case snow, ice and rock—can furthermore be used to estimate the mass.

ONLINE DATA SHARING PORTAL

After data collection and analysis, it was important the data was effectively visualized and could be readily shared with MoTI personnel. To achieve this, we built an online data visualization and sharing portal using Geoserver, R, and RShiny that was installed on the Microsoft Azure platform. For each mission, the orthomosaic, DEM, and all individual photos on which the orthomosaic and DEM were based could be viewed.

The snow depth for each mapping can be viewed in a map where the colour represents the snow depth (Figure 2, bottom right). The portal is designed to aid avalanche mitigation measures in a short time window: for example, by assessing the effectiveness of control measures or assessing the snow depth at the end of season to determine the need for ongoing monitoring. It can also function as an archive to compare historic conditions.

The portal has been designed around the immediate needs of the Coast–Chilcotin Avalanche Program but it can be adjusted and expanded. Different data results can be uploaded with different priorities. The geotagged raw imagery of the flight can be uploaded immediately post-flight allowing for instant visual inspection, as well as the snow depths once post-processing, photogrammetry and analysis is finished (typically one or two days). Aspects of the data visualization can be adjusted, such as the size, transparency, and range of snow depth of the grid cells.

IMPLEMENTATION

Implementation of a program for aerial monitoring of avalanche hazards can be divided into three stages: set-up, data collection, and data analysis and sharing.

The set-up starts with an assessment of the areas of interest, which determines the choice of RPAS. Small areas (less than 0.25 km2) such as avalanche debris flows can be covered with a small multirotor with RTK/PPK in a single flight. The cost for one of these starts at about $12,000 (DJI Phantom 4 Pro RTK). Larger areas and/or large elevation gains benefit from a fixed-wing RPAS, which starts at around $40,000 (eBee RTK); or a VTOL, which starts at around $34,000 (Quantum Systems F90+). Prices are approximate and include a GNSS base station for RTK/PPK and one battery. An extra battery costs between $250 to $1,200 and a tablet or laptop is required as a base station.

Personnel should obtain Transport Canada RPAS certification (an online exam that currently costs $25) and get flight and mission planning training. Lastly, flight mission plans have to be made for the sites of interest and tested before data acquisition.

The data acquisition phase starts with obtaining a reference DEM of the barren ground in summer to estimate absolute snow depth, or early in winter with a minimal snowpack. Subsequent data collection missions can be conducted by the avalanche technicians or other trained RPAS pilots.

During the third phase, the data has to be uploaded to the cloud (this requires fast internet) for post-processing and analysis, and the results can be made accessible through a secure web portal. If the analysis is not time sensitive, the data could also be transferred at the end of the season onto a hard drive and analyzed all at once.

CONCLUSION AND FUTURE PROSPECTS

Our results show that RPAS can be used to provide valuable complementary information for avalanche technicians for their hazard analysis and control work, and for validating field-based observations such as avalanche volumes and start zone snow supply. Over time, these data sets will turn into valuable time series that can further improve forecasting.

Looking into the future, the effectiveness of aerial monitoring will further improve with the continuing increase of reliability of RPAS. Extending flight times will lead to a wider utility of multirotors to monitor larger surface areas. Furthermore, different payloads are being integrated. Lidar, especially, will open new opportunities. Ground penetrating lidar can be used to improve the barren-ground reference DEM by controlling for the height of the vegetation, which can be a substantial source of variation. The technological advances combined with the progression of beyond-visual-line-of-sight regulations by Transport Canada will further benefit the utility of unmanned aerial systems for snow avalanche monitoring purposes.

ACKNOWLEDGMENT

We would like to thank Julie McBride and Jeff Van Driel from the MoTI Coast–Chilcotin Avalanche Program, and Ryan Boyle and Bree Stefanson from the Bear Pass Program for their help and great company while collecting the data. Robb Andersen and Rodrigo Disegni deserve a big thank you for making this project possible.

in the loupe

36

HOW IS THE AVALANCHE PROBLEM INFORMATION USED?

in this **section**

// BRAD HARRISON

Terrain Use as a Lens For Understanding Decision Making in Avalanche Terrain

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IN AVALANCHE CLASSES, we often teach backcountry skiers and riders that when the snowpack is your problem, terrain is your solution. Only time can heal a poor snowpack, but you can adapt your terrain selection to help mitigate the risk. Even under the most challenging circumstances, careful terrain selection can reduce or even eliminate your avalanche exposure.

While many of us can correctly identify safe and dangerous avalanche terrain given the prevailing snowpack conditions, we may not always choose to use the safest possible terrain. Maybe we want to ride a slightly steeper line we still deem reasonable for given conditions. Maybe we have a specific objective in mind. Maybe our group wants to ski something riskier than our own personal preference and we give into peer pressure. As human beings we are social creatures by nature and our actions are either consciously or unconsciously influenced by who we are with, the groups we associate or aspire to be with (Mannberg et al., 2020), and the culture of the sport. Sometimes these influences are positive and yield safer choices, and sometimes they don't.

Regardless of the choices we make, how we respond to all of these physical and human factors, and a multitude of other issues, the sum of these decisions and our responses are ultimately expressed in the line we leave in the snow. It is our path across the landscape. This track is the culmination of many factors that result in our decision to ride a specific line. If we take a terrain-focused geographic view, we can think of that line we leave in the snow as the geographic expression of the sum of all our personal and group decisions in the backcountry. In very real terms it reflects our thinking about how we avoid risk. This means that if we can record your track and also understand something about your individual and group's skills, experience, motivations, and goals, that we might be able to say something about your decision making, and ultimately about your avalanche risk exposure.

For almost a decade we have been using this geo-spatial approach to understand the decision making of different groups under varying circumstances using a range of different methods to provide an improved understanding of real-world decision making in avalanche terrain. The overall goal of this work is to understand the situations (i.e. in space and time), the demographics (i.e. age, gender, experience etc…), and the social scenarios (i.e. group dynamics) that influence risk taking behavior. We can use this information for targeted education and to reduce avalanche fatalities through better understanding of the "human factor." This article presents a summary of some of the work completed within our wider research group on this topic. References are included if you want to dig in deeper on any of these themes.

THE SKITRACKS PROJECT

Our work started following ISSW 2012 when Jerry Johnson and Jordy Hendrikx (both professors at Montana State University) had a chance meeting and a conversation about surveying skiers and tracking them to understand decision making in avalanche terrain. This evolved into The SkiTracks Project, a large crowd-sourcing project that aimed to collect both spatial and survey data from backcountry skiers and sledders from all around the world (Hendrikx and Johnson, 2014, 2016a, 2016b; Johnson and Hendrikx, 2021).

This work was focused on documenting real-world terrain use via GPS from a smartphone app. We combined the tracks with demographics from a survey in order to provide insight on who made up the backcountry population, group demographics, where people went, and how that changed as a function of the snowpack and avalanche danger rating. While this work was successful in collecting these data and has provided insights on how different groups behaved, it provided limited understanding of why these differences were present. What motivated observed differences in terrain use that snowpack conditions couldn't explain? The other limitation was the bias in our sample. We collected data from mostly intermediate to expert skiers and riders—those that are most engaged in the backcountry—so our scope of inference was limited to this subset of our community.

INTERCEPT SURVEYS

In an effort to sample a broader swath of the backcountry population, we have used intercept surveys to literally intercept people as they headed into the backcountry. Building on prior work in Europe and locally (e.g. Procter et al., 2013, Fitzgerald et al., 2016), John Sykes (an MSc student at the time, and now PhD student at Simon Fraser University) completed a focused survey to understand who, where, and how people used terrain in the Saddle Peak backcountry area

RESEARCHER JOHN SYKES, LEFT, CONDUCTS AN INTERCEPT SURVEY AT THE BOUNDARY OF BRIDGER BOWL. // JORDY HENDRIKX

adjacent to Bridger Bowl Ski Area in southwest Montana. Standing at the Bridger backcountry boundary, John stopped people and asked them to carry a GPS and record their track. Upon returning to the ski area, they turned in their GPS and completed a short survey on the way back up the lift.

Consistent with prior work, gender and formal avalanche education were shown to be important with regards to terrain choice and exposure (Sykes at et al., 2020). Interestingly, Sykes et al. also showed that in this lift-accessed backcountry setting, there was confusion about avalanche mitigation in these backcountry areas that also influenced the use of higher-risk terrain. Many people were under the misunderstanding that ski patrol managed the backcountry areas near the boundary—a potentially fatal mistake.

While intercept surveys are a powerful tool to capture a large proportion of people in one area, they are very time consuming and due to the number of people required for robust samples they have a limited spatial extent of only a few specific trailheads unless you have an army of volunteers.

TIME-LAPSE PHOTOGRAPHY

Using crowd-sourced data and intercept survey data yielded some valuable insights, but we were still not necessarily capturing the terrain choices by everyone. Not everyone wants to take a survey and not everyone wants to participate in a research project and submit tracks. So, in another attempt to understand terrain use by backcountry users, Diana Saly (a MSc student at the time, and now Avalanche Canada forecaster) deployed a time-lapse camera to track people as they moved in a backcountry area.

Again, we used Saddle Peak adjacent to Bridger Bowl as the study area. Using this remote time-lapse, we anonymously recorded the descent route of riders in 10-second increments. Diana used 31,966 images over 13 days and 7,499 skier point locations to extract terrain metrics for each rider location. Analysis of these data showed a substantial number of solo skiers in this very committing terrain, but also that terrain choices changed on considerable danger days, with slightly lower slope angles used and greater avoidance of significant hazardous terrain features (e.g. the large cliff-band feature in the middle of the slope).

By remotely photographing all skiers on a slope (pending visibility), we collected a large and diverse data set of the terrain preferences of backcountry skiers under varying avalanche conditions, with limited selection bias. While this did not provide insight on who these individuals were, it did provide a more complete understanding of where these people went when they didn't know they were being watched. Diana also showed using a time-lapse camera had operational value by documenting avalanche events and allowing first responders to review images just minutes after an event in order to ascertain if anyone had been caught. An excellent case study of this application was presented in Saly et al., (2016).

This brought us closer to understanding behavior, but it was the last step that gave us deep insight into the psyche of some skiers.

BEHAVIOURAL ECONOMICS

By leveraging approaches used in behavioural economics and psychology, we used hypothetical scenarios to understand decision making using a discrete choice survey approach. Similar to prior work (e.g. Haegeli et al., 2010; Marengo et al., 2017), Mannberg et al. (2018, 2020) presented participants with information about avalanche conditions and a set of different routes down a mountain that represented different levels of risk. We then asked them which run they would prefer to ski and which run they would accept to ski if someone in their group wanted to do so. We found risk preferences of one's peers motivated riders to take more risk.

DIANA SALY SETS UP HER TIME-LAPSE CAMERA, WITH THE SADDLE PEAK BACKCOUNTRY AREA IN THE BACKGROUND (LEFT HAND SIDE, SKYLINE RIDGE AND FACE WITH CLIFF BAND). // JORDY HENDRIKX

Using this same approach, Mannberg et al. (2020) explored the role of positionality—the desire to gain social status via our behaviors—on the willingness to ride risky terrain. We found positional riders, which made up approximately 33% of the sample, were significantly more likely to boast about riding bold lines on social media, more likely to associate steep riding with social respect, and, critically, more likely to say they would accept to ride a potentially risky line if their companions wanted to. Mannberg et al. (2020), also noted this positionality effect is present regardless of level of avalanche training.

This innovative work highlights the role of social factors with respect to risk-taking and suggests a greater consideration of these factors should be included in avalanche courses. However, they also note they use hypothetical choices as a proxy for risk-taking behavior, and that responses to hypothetical questions may differ from real life behaviour, especially if participants are motivated to provide "correct" answers (Mannberg et al., 2020). This highlights the difficulty of understanding human behaviors.

CONCLUSION

Each of these different methods have provided different insights into terrain use, terrain preference, and decision making in avalanche terrain. Each method has its own strengths and weaknesses in respect to how it captures the where, who, when, and why of decision making in avalanche terrain. Individually, each method has its own deficiencies but collectively, and especially when combined, they provide a comprehensive view of how, where, when, who, and why we make the decisions we do in the backcountry. These are critical insights to more fully understand how decisions are made and, more critically, how we can help improve those decisions in high-risk situations where an error, either through ignorance or by choice, could result in a fatality.

Future work will further expand on merging the hypothetical discrete choice analysis with the SkiTracks crowd-sourced data to better understand how survey responses in a hypothetical situation might relate to real-world choices in the backcountry (e.g. Hendrikx et al., 2018). We also want to improve on how we express risk by using an ATES-based terrain analysis approach, which is dependent on ATES mapping across larger areas such as exists in Norway (Larsen et al., 2020) and are moving towards in other areas (Larsen et al., 2020). While incremental, each of these studies have provided additional insight and make a contribution to understanding decision making in avalanche terrain.

How you move in avalanche terrain reflects the sum of the factors that you have explicitly or implicitly weighed on some level—consciously or subconsciously. The track represents your ultimate decisions due to proximate causes. The next time you venture into the backcountry, think about what your track says about your decisions and how it changes as a function of the snowpack conditions, your group, your motivations, and your risk tolerance. Does it represent the level of risk you wanted to accept, or did the thrill of powder or unconscious bias and social factors nudge you to take a riskier route? Thinking critically about your track could help you think more critically about your terrain choices, the reasons for them, and what that says about you.

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How is the Avalanche Problem Information Used?

Pascal Haegeli and the SARP Research Team

OVER THE LAST FEW WINTERS, my research team and I have conducted several large online surveys to better understand how backcountry recreationists use avalanche bulletins. We are typically interested in big questions like "What are the different types of bulletin users?", "Do our users have the skills they need to apply the bulletin information in a meaningful way?" and "How does the presentation of the information affect users' ability to apply the information?" However, not all the data we collect make it into our final analyses and presentations. This article shares some additional insight we gained from our 2020 survey on how people use the avalanche problem information provided in avalanche bulletins.

How often do you check the avalanche problem information when you read the avalanche forecast?

Of the 3,328 participants who completed this part of our survey, 71% said they always check the avalanche problem information when they read the bulletin, 22% check it most of the time, and less than 1% stated they never read it. This high engagement is not surprising because our sample had a fairly high level of avalanche training. Eighty-one percent had at least an introductory course like an AST 1, and our analysis showed a clear association between level of training and how often people say they check the avalanche problem information.

How much weight do you give this information when you check it?

Checking avalanche problem information is one thing, but how important is this information in people's decision-making process? To examine this question, we asked everybody who said they check the avalanche problem section at least 'rarely' how much weight they give each of the avalanche problem components (elevation, aspect, chances of avalanches, and expected size). The response options were none, a little amount, a considerable amount, a large amount, and a large amount depending on the avalanche problem. These terms, though general, can provide us with a sense of how avalanche bulletin users value this information for their decision-making process.

Figure 1 provides a first overview of the responses. For this perspective, we combined the "a large amount" and "a large amount depending on the avalanche problem" categories. Overall, participants stated they weigh the elevation information the most, followed by the aspect and likelihood information, and the size information is distant last. These differences are statistically significant.

While these statistics are interesting, we can gain deeper insight by exploring whether there are distinct patterns in how our survey participants answered these questions. To shed light on this we used a statistical method called latent class analysis that not only identifies the patterns but also determines which pattern each participant belongs to. Because the avalanche problem information is presented differently in Canada and the U.S., where elevation and aspect

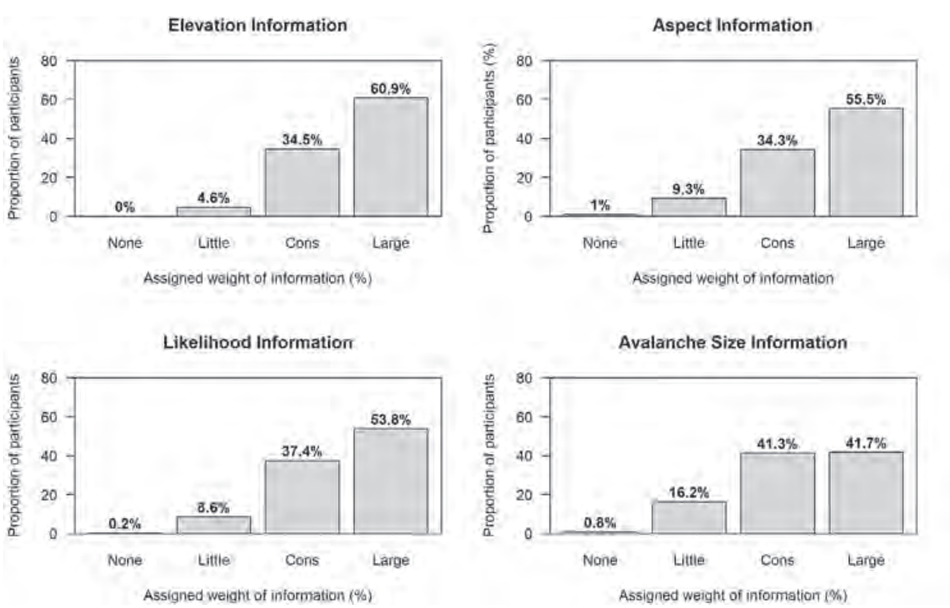

FIG. 1: OVERVIEW OF RESPONSES TO QUESTION ABOUT WEIGHING OF AVALANCHE PROBLEM INFORMATION.

Pattern 1: Little to considerable amounts of weight
20% of Canadian sample

Use of information	*Rarely*	*Occas*	*Most*	*Always*	
	6%	12%	35%	47%	
Weighing of info	***None***	***Little***	***Cons***	***Large***	***AvProb***
Elevation		14%	59%	25%	2%
Aspect	5%	27%	47%	20%	1%
Likelihood	2%	43%	15%	40%	0%
Expected size	3%	46%	28%	23%	0%

Pattern 3: Consistent large amount of weight on information
30% of Canadian sample

Use of information	*Rarely*	*Occas*	*Most*	*Always*	
	0%	1%	15%	84%	
Weighing of info	***None***	***Little***	***Cons***	***Large***	***AvProb***
Elevation	0%	1%	9%	88%	2%
Aspect	0%	2%	12%	85%	1%
Likelihood	0%	1%	1%	97%	0%
Expected size	1%	1%	7%	91%	0%

Pattern 2: Considerable to large amounts of weight
45% of Canadian sample

Use of information	*Rarely*	*Occas*	*Most*	*Always*	
	0%	3%	23%	75%	
Weighing of info	***None***	***Little***	***Cons***	***Large***	***AvProb***
Elevation	0%	3%	44%	51%	2%
Aspect	0%	7%	47%	43%	3%
Likelihood	0%	2%	70%	27%	1%
Expected size	0%	9%	67%	23%	0%

Pattern 4: Weighs information depending on avalanche problems
5% of Canadian sample

Use of information	*Rarely*	*Occas*	*Most*	*Always*	
	0%	2%	5%	93%	
Weighing of info	***None***	***Little***	***Cons***	***Large***	***AvProb***
Elevation	0%	3%	0%	24%	73%
Aspect	0%	1%	0%	16%	83%
Likelihood	0%	7%	27%	27%	39%
Expected size	0%	5%	21%	42%	32%

FIG. 2: CANADIAN RESPONSE PATTERNS FOR THE USE AND WEIGHING OF AVALANCHE PROBLEM INFORMATION WITH SHADED PERCENTAGE VALUES. DARKER SHADES INDICATE HIGHER LIKELIHOOD OF THE RESPONSE OPTION BEING PICKED.

information is combined, we conducted a separate analysis for each country.

The analysis of our Canadian sample (1,014 participants) revealed four distinct patterns in how people answered our avalanche problem questions. The results are illustrated in Figure 2, where the shaded percentage values indicate how the participants assigned to the different patterns responded to our questions. For example, 47% of the participants that were assigned to Pattern 1 picked "always" as their answer for the use questions, whereas it was 75% for the participants who were assigned to Pattern 2.

When you look at the shaded percentage values in Figure 2, you can see the four patterns that emerged can be organized into a hierarchy where both checking the avalanche problem information and the weight it receives in participants' decision-making processes continuously increase.

At the very top of this hierarchy is Pattern 4, which covered 5% of our Canadian sample. Almost all of these participants always look at the avalanche problem information and tend to weight the information depending on the avalanche problem type—especially elevation and aspect. They give considerably less weight to likelihood and size.

To find out more about the avalanche problem dependent interpretation of the information, our survey included a follow-up question where participants who chose the "a large amount depending on the avalanche problem" option could indicate for which avalanche problem types they weigh the information heavily. Wind slab, persistent slab, and deep persistent slab were consistently among the problem types where the detailed problem information was weighed more heavily, but their order differed between the location details and the likelihood and size information. The location information was weighted more heavily for wind slabs, whereas the weight of the likelihood and size information was higher for persistent and deep persistent slabs.

The avalanche problem types where location information got less weight seem to either be widespread problems like storm slabs or dry loose avalanches, or problems like wet loose avalanches that are tied to aspects that typically do not change over time (e.g. solar aspects). These results show these users have a nuanced understanding of avalanche problems and use the avalanche problem information accordingly.

Pattern 3, which covered 30% of our Canadian sample, consists of survey participants of whom the majority still always check the avalanche problem information, but the distinct characteristic of this pattern is they give all of the avalanche problem information a large amount of weight regardless of the problem type. Interestingly, they seem to give the likelihood and expected size information slightly more weight than the location information, which is different from what we saw in Pattern 4.

In Pattern 2, the proportion of participants that always look at the avalanche problem information drops to 75%. In parallel, the weight participants in this pattern assign to the information decreases. In comparison to Pattern 3, the participants included in Pattern 2 tend to pay substantially more attention to the location information. With 45% of Canadian participants assigned to this pattern, it is the largest that emerged from the analysis.

The remaining 20% of the Canadian survey sample was assigned to Pattern 1, where less than half always check the avalanche problem information, and even less weight is put on this information. The location information gets more attention than the expected size information, but there is an interesting split in the distribution for the weight of likelihood, with 43% giving it only a little weight and 40% giving it a large amount of weight. This should be investigated further.

Who are the participants using the avalanche problem information in these different ways?

Knowing these use patterns is interesting but to make this information more useful we need to understand who uses the avalanche problem information in these different ways and why. To examine this question, we used a method called a conditional inference tree to see what participant characteristics are associated with the different patterns. For this analysis, we included participants' age category, self-

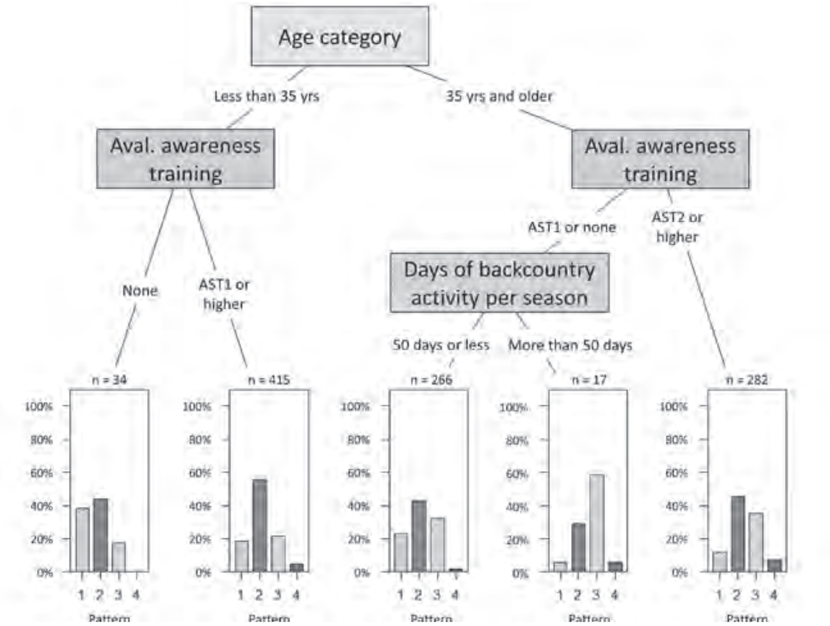

FIG. 3: CONDITIONAL INFERENCE TREE ILLUSTRATING HOW PARTICIPANTS' CHARACTERISTIC IN THE CANADIAN SAMPLE RELATE TO AVALANCHE PROBLEM INFORMATION USE PATTERNS (1014 PARTICIPANTS).

identified gender, primary winter backcountry activity, level of formal avalanche training, years of experience, and days of winter backcountry activity per season.

The results are illustrated in Figure 3. The tree structure highlights which characteristics have a statistically significant relationship with the avalanche problem information use patterns. The bar charts show the distribution of the use patterns among the participants with the particular combination of characteristics.

The characteristics that were identified as having a significant relationship with the information use patterns were age, avalanche awareness training, and number of days of backcountry activity per winter. Somewhat surprisingly, age emerged as the most important background characteristic, which is shown at the very top of the tree in Figure 3. Participants younger than 35 had a higher chance of belonging to Patterns 1 and 2, and used avalanche problem information in a less sophisticated way than participants who were 35 and older.

Avalanche awareness training emerged as the second most important background variable for both the younger and older participants. Among younger participants, introductory avalanche awareness training (AST 1) decreased the proportion of Pattern 1 users and increased the proportion of Pattern 2 users substantially. Among older participants, advanced avalanche awareness training (AST 2 or higher) resulted in a higher percentage of Pattern 4 users. These are the folks that interpret the information depending on the avalanche problem type.

In addition, **number of days of backcountry activity per season** identified a small group 35-or-older with AST 1 or no formal avalanche awareness training that spends more than 50 days in the backcountry per winter. This group had the highest proportion of Pattern 3 users, who check the avalanche problem information all the time and consistently give it a lot of weight. However, with only 17 participants, this is a rather small group and we should not over-interpret this split.

CONCLUSION

I hope this analysis gave you some interesting insight about how Canadians use the available avalanche problem information. Our analysis of the American survey sample (2,280 participants) showed very similar patterns and confirm the general trends presented here. My main conclusion from these analyses is the avalanche problem information included in avalanche bulletins is being used in distinct ways, and while avalanche education plays an important role in how people use the information, other characteristics such as age and number of days in the backcountry per season also seem to have an effect.

At this point, I do not have a good explanation for the influence of these background characteristics yet, but their presence is consistent with the results of other recent SARP risk communication research projects by Anne St. Clair, Henry Finn, Katie Fisher, and Abby Morgan. To me this means the factors affecting people's use of the bulletin information are manyfold and the relationships are messy. However, working towards a more systematic understanding of the different ways people use avalanche bulletins, who these people are, and why they use it that way is critical for improving the bulletin and making our products resonate better with all types of users.

If you have any comments or suggestions about this study, please contact us as we are always keen to hear about your perspectives and new ideas for this type of research.

Recent SARP articles on our social science research on avalanche bulletin users

St. Clair, A. Finn, H., Haegeli, P., Klassen, K., and Gregory, R. (2020). How getting to know the recreational audience can improve the effectiveness of the avalanche bulletin. *The Avalanche Journal*, 123, 28-31.

Finn, H., St. Clair, A., Haegeli, P., Klassen, K., Clayton, M., and Gregory, R. (2020). Do recreationists have the skills they need to use avalanche bulletins effectively? *The Avalanche Journal*, 124, 32-34.

snow globe

in this **section**

// CURTIS PAWLIUK

One Year Later

Adam Campbell and Kevin Hjertaas

ADAM CAMPBELL WITH HIS LATE WIFE LAURA KOSAKOSKI. // ADAM CAMPBELL COLLECTION

On January 10, 2020, Adam Campbell, Kevin Hjertaas, and Laura Kosakoski, were out ski touring on Mount Hector in Banff National Park when they triggered an avalanche that resulted in Laura's death. The events of that day have been reported on extensively, but how do you recover emotionally after such a tragedy?

One year later, Adam, Laura's husband and director with the Avalanche Canada Foundation, and Kevin, their friend and an ACMG Ski Guide, reflect on their healing journeys since that day. We hope their experiences can help others navigate their own trauma should they ever find themselves in a similar place.

COPING WITH LOSS Adam Campbell

ON JANUARY 10, 2020, I stepped forward onto a wind-loaded feature that triggered an avalanche that ultimately buried and killed my wife, Laura Kosakoski. I have to grapple with the fact that I caused the avalanche, but also that I was then unable to get to her in time and save her. There were many days, especially early on, when I didn't know if I could live with that reality. I remember walking along a frozen Bow River in Canmore a few days after the accident and thinking how much easier everything would be if I jumped. The only thing that kept me from taking that step was thinking about the further pain that would cause those I love. I chose not to jump for their sake and not my own.

Laura was my emotional support. How was I supposed to cope with things having lost that emotional support? I relied heavily on my friends and family in the days after the avalanche. Largely unable to care for myself, people would bring me food, many of them total strangers. This deep level of love, support, generosity, and help in my darkest hour touched me deeply. Accepting this help and kindness was a big first step in my initial healing. A part of me wanted to punish myself and hide away, but accepting the fact that I would not be able to move forward alone allowed me to open myself up to this much needed help. They helped guide me through the fog.

Having used counselling in the past, I sought professional help almost immediately. My family pushed me to go and get it too. I am glad I listened. Much like a physical wound, I recognized the sooner I could start addressing my emotional injuries, the more likely I was to be able to make a more full, long-term recovery from them. The initial sessions were very raw, but they did help me set the intention that I would try and deal with the trauma I was experiencing. I continued to seek regular counselling and the sessions have evolved, along with experience of the day.

I also sought professional medical help. I was unable to sleep for weeks after the avalanche and my sleep remained poor for months. Laura was a medical doctor and she changed my view on sleep and mood medications in many of our conversations about them. She helped me understand they are bad if misused, but that they can also help bring you back to a place of homeostasis. Sleep is critical to life and emotional control, so using tools to try and get some sleep and emotional control helped me get my feet under me. I come from a family with substance abuse issues and I am prone to them myself. I tried to not let them get hold of me and I made myself abstain from recreational drugs and alcohol, fearing the slippery slope that they might lead me down.

I am not religious, but Laura's mom is deeply spiritual and she arranged a meditation with a friend who's a Buddhist nun a few days after the avalanche. I joined in on this meditation and although my brain continued to be out of control for the bulk of the session, I did feel a brief second of calm during the process. Over the following months I continued this practice—it has been rewarding.

Like many people reading this, I am physical person and I find great solace in nature. Despite my fatigue, friends picked me up and took me cross-country skiing, running, and climbing at the gym. Many days, these activities were mostly just walks where I would break down and cry, but they were very important to me in my healing. I have since gone on to visit many of the places that were special to me and Laura. This includes going to the site of Laura's avalanche, once in the summer and another time on the one-year anniversary of her death. I held a small ceremony in those places and spread her ashes. These ceremonies have been an important part in redefining my relationship with the mountains.

There is no roadmap for moving forward after a traumatic tragedy. Rather, in the days, weeks and months after the avalanche I found myself in a deep emotional and cognitive fog, enveloped in fear, confusion and tears. Trauma and grief cracked me open and my emotions poured out of me. I found myself in a feral, reactive state. Nothing I had experienced prior to that day could have prepared me for it. The most seemingly innocuous of reminders of Laura would bring me to my knees. Over time that reactive state has loosened its hold a bit and I am increasingly able to plan ahead and look forward.

In no way will I pretend to say that my life is what it was prior to the avalanche and I will forever be changed and affected by it. Accepting that reality has been part of my healing. Relying on my community, seeking professional help, and looking after my emotional and physical health are what I am using to help me find what my new normal will look like.

ADAM CONTINUES TO WORK ON HIS HEALING PROCESS. // ADAM CAMPBELL COLLECTION

THE PENDULUM EFFECT Kevin Hjertaas

Alongside Adam's account, any impact the avalanche and Laura's death has had on me will seem trivial. But it had an impact. And though every accident and every person is different, there might be value in sharing what those impacts can be on one's career and life.

On Jan. 10, 2020, during a recreational day, an avalanche buried Laura deep. It was a challenging search and the digging took us over an hour. Physically and emotionally, it was shattering. Now, I can't decide what details were the most traumatizing. It might just be the hours spent redlining on panic, effort, and despair. After a blur of helicopters, rescuers, and police, we paused on our way to the hospital to give statements at the RCMP station in Lake Louise.

It was there that a kind woman from Victim Services met us, showed us tenderness, and added a human touch in the middle of the tempest. It's a fog looking back, but I think that's where the plan for professional therapy was made or at least discussed and committed to.

That discussion and a rapid offer from the ACMG to cover the initial costs of therapy were crucial in hindsight. Therapy is expensive, especially if you can't imagine going back to work anytime soon. More importantly, it was a solid nudge to ignore the stigma, vulnerability, and fear, and walk through that door.

Perhaps if I guided as part of an organized and supportive team, I could have jumped back into work, but so much of working in avalanche terrain comes down to decision making and it would have been indefensible to be out there in the headspace I was in. A month before my ski guide's exam in 2014, I'd had a particularly traumatic month ski patrolling that taught me that lesson. It was a month of tough callouts, avalanches, and fatalities, and I showed up for that exam unprepared and overwhelmed. It was a resounding failure.

When the negative outcomes of avalanches and ski accidents are raw in your psyche, it's reasonable to be overly-conservative. But my risk acceptance swung like a pendulum erratically day to day. I was the classic exam head case as I battled to override and hide fear. Years

KEVIN WORKS ON CULTIVATING THE MENTAL RESILIENCE TO MAKE HONEST AND WISE DECISIONS IN THE MOUNTAINS. // KEVIN HJERTAAS COLLECTION

later, I could look back and see the effect of trauma on my decision making and how dangerous it could have been in an unsupervised environment.

That pendulum effect, I believe, comes from an inability to occupy the balanced middle ground—a physical resistance to sit with uncertainty and be open to it. On that exam, I could act boldly or conservatively. I could not, in serious situations, calmly sit in between and analyze the group's safety.

The year since Laura's death has been like that, but with space and professional help, I can see the illogical swings more clearly. First, there was a need to flee the life that had led to such a horrible accident. My wife closed her small business, and we looked for jobs and homes in the prairies or on the coast.

When COVID-19 stopped the world, we had time to breathe and realize how lucky we are to live in the mountains of Western Canada, but I still believed I'd never want to go into those mountains again. Months later, some nights my mood would lift and I'd lay awake dreaming of peaks and long powder runs, but the next day I'd swing back down, hard. At one point, I was so convinced that the risks of backcountry skiing were unwarranted, that not only should I give it up, but I should spend my days evangelizing and convincing others to quit doing it.

Luckily, remorse slows ambition and I never did get a soapbox or find a new career. Instead, I found a new appreciation for our mountain community and that community pulled me back in—or not pulled me as much as held me and offered support along with dozens of invitations. Ten months after the avalanche, I accepted one of those invitations to go skiing. I didn't enjoy all of it, but I did enjoy being out with great people in beautiful mountains. Weeks later, I tried again.

Eventually, I even tried guiding. First tail guiding and then guiding closely with a trusted co-worker and friend. It was enjoyable, but also a bit too much. Luckily, this time I'd anticipated it and before the pendulum could swing far, I could hand over the reins. A younger, more ambitious guide could have forged ahead, I'm sure, but I'm content to wait for the swings to ease.

In the meantime, I'll enjoy mellow tours in the trees while keeping a skeptical eye on my urges to undertake solo bold descents. And I'll try to cultivate the mental resilience to make honest and wise decisions in the mountains somewhere between the pendulum swings.

I'm certainly no expert, but in the last year, I've talked to many mountain professionals about similar experiences. Everyone has different ways of healing or taking care of themselves, but getting professional help as early as possible seems universally beneficial.

In response to traumatic incidents, we go into a defensive state that has mental and physical responses. The longer we stay in that mode, the more we become hardwired for it. It's an emotionally stunted and easily triggered state. A therapist trained to handle trauma responses can help you move past that towards a healthier life.

The challenge, in my experience, is to recognize your need at the time. That's why it's helpful to commit beforehand to see a therapist if things go wrong as part of your critical incident response, even if you don't think you need it in the moment.

Cultures of **Risk Management**

Jerry Isaak

How stories and symbols endure as humanity's most powerful tool for survival in avalanche terrain.

MODERN AVALANCHE PROFESSIONALS have powerful tools at their disposal to mitigate the risk of living, working, and traveling in avalanche terrain. Hand-thrown explosive charges, 105mm howitzers, and remote avalanche control systems all contribute to mitigate avalanche hazards in the modern age. Yet none of these tools are as singularly effective or as globally applied as culture—humanity's oldest tool for adapting to avalanches.

At first glance it may seem absurd that the stuff of culture[1]—a story, symbol, or ritual—could play a globally powerful role in reducing or responding to avalanche hazards, especially in the 21st century. However, a closer look reveals that human responses to avalanches have included cultural dimensions since the very first time our ancestors encountered sliding snow, and that these ancient practices and knowledge continue to shape our response to living with natural hazards.

There are no records of the first human who was caught and carried by an avalanche. We don't know their name or what they thought as snow shifted beneath their feet and swept them down a slope. No incident report communicates the size of the slide or if the person survived. We can only speculate on where the avalanche may have occurred. All evidence has long since melted away in the millennia between this moment and that.

We know nothing of the event itself, yet we can know one thing with certainty: that moment, the first instance a person was present when *the snow slid* and *the ground moved*, contradicted all existing human knowledge. The prior experience of a thousand generations—the sum of all wisdom until that day—attested that snow on the ground was firm and trustworthy. Until it wasn't.

If the first person caught in an avalanche survived, they would have returned to their tribe or family group with quite a story to tell. But what could that story be? What words can explain an event that contradicts all prior knowledge and experience? Why did the snow slide and, more importantly, what did it mean? An explanation for this new knowledge would had to have been as much cultural as it was technical. A new story was required in order to ascribe meaning to the movement of snow.

A shifting world view in response to natural hazards is universal, to the extent that "every human society maintains its sense of identity with a set of stories which explained, at least to its satisfaction, how things came to be" (Deloria, 1995). For early humans, making meaning out of hazards in the natural world allowed for the creation of collective outlooks and behaviours that enabled communities to devise and implement strategies to respond to the hazard. While

"EX-VOTO FOR SURVIVING AN AVALANCHE IN AUSTRIA (1817)" - WHEN TRAGEDY STRUCK, COMMUNITIES ESTABLISHED "CULTURES OF MEMORY" THROUGH THE CREATION AND DISPLAY OF MEMORIAL VOTIVE (EX-VOTO) TABLETS.

[1]Culture, defined here as the "symbols that express meaning, including beliefs, rituals, art and stories that create collective outlooks and behaviours" (Swidler, 1986).

modern avalanche forecasting and mitigation infrastructure is only about 150 years old, human attempts to comprehend and explain avalanches began immediately after witnessing that very first slide (Haid, 2007; Revelstoke Museum & Archives, 2015).

Societies around the world respond to natural hazards like avalanches through the development of cultures of risk management, which include not only technical solutions but also cultural strategies for survival (Bode, 2001; Simpson, 2002; UNESCO, n.d.). These cultural responses evolved as humanity's ancient tools for making sense of the world, for creating meaning out of chaos, and for adapting to hazards. Beyond stories, cultural elements include oral traditions and expressions, language, performing arts, social practices, ritual and festive events, and traditional craftsmanship. In recognition of cultures of risk management, in 2018 UNESCO added "Avalanche Risk Management" in Austria and Switzerland to the List of the Intangible Cultural Heritage of Humanity, illustrating "the fact that natural hazards are not mere technical challenges but also cultural challenges that each society addresses in its own way" (UNESCO, n.d.).

Indeed, while all cultures use symbolism to depict and explain disasters, the global nature of avalanches leads to diverse cultural expressions in mountain communities around the world (Hoffman, 2002). In the Alps, avalanche-related narratives include centuries-old accounts of witch trials, accusations of sorcery, and theological explanations for avalanche tragedies. Bells were rung, chapels were built directly in slide paths, and annual processions marched through villages, all in attempt to ward off avalanche disaster (Fraser, 1966). When tragedy struck, communities established "cultures of memory" through the creation and display of memorial votive (ex-voto) tablets and—especially—with place names that highlighted the avalanche hazard (Rohr, 2009). These cultures of memory persist today, including through votive images that commemorate avalanche tragedies from 500 years ago and the many locations throughout the Alps with names derived from avalanche events (Haid, 2007).

Avalanches feature in the histories of virtually every mountain community and are described in sources as diverse as Sanskrit lyric poetry of the Himalayas (ca. 400 CE), the travel journals of a seventh century Chinese monk, and 900-year-old Icelandic sagas (Edgerton & Edgerton, 1964; Li & Rongxi, 1996; McGrew & Thomas, 1974). Additionally, the oral traditions of many indigenous peoples—from the coastal mountains of British Columbia to the Khibiny Peninsula of northwest Russia—incorporate avalanche hazards into sophisticated worldviews and histories (Cruikshank, 2005; Zmeeva & Razumova, 2017).

Yet despite diverse local practices, cultural expressions, regardless of geographical location, appear to play a critical role in the formation of an infrastructure of social protection: enhancing coping, hazard mitigation, and providing a context in which to comprehend future events.

Although they are among humanity's oldest strategies for survival, stories and symbols remain universally powerful tools for mitigating avalanche risk. The stuff of culture is part of everyday practice for avalanche professionals. Stories and symbols are employed daily by forecasters to communicate avalanche hazards to the general public, teams of ski guides perform daily rituals of guide's meetings and information sharing, and ski patrollers discuss past events and individuals in order to lend meaning to present snowpack instabilities.

Most poignantly, following avalanche fatalities, cultural practices can be observed in the established formal and informal rituals of investigation, reflection, and physical and virtual memorials. The community and practice of avalanche professionals is infused with cultural history and meaning. Although human beings have developed modern tools and techniques for coexistence with natural hazards, our most powerful tools are composed of the same basic cultural building blocks that were expressed by the very first human caught in an avalanche: story: symbol and ritual.

For avalanche professionals and readers of *The Avalanche Journal*, what contributes to cultures of risk management in your own practice? Consider the stories you tell, symbols you employ, and rituals you perform as you build and share cultures of risk management with the next generation of professionals.

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SOME MEMBERS OF THE VSSW TEAM CELEBRATES AFTER HOSTING A SUCCESSFUL ONLINE CONFERENCE IN THE FALL. UNFORTUNATELY, THEY WILL NOT BE ABLE TO HOST ATTENDEES IN PERSON. // JENNIFER COULTER

The Ride is Over
ISSW Fernie Cancelled Due to COVID-19

Mary Clayton

IT WAS A BIG AMBITION to host an international conference in small-town B.C. Instead of a high-tech conference centre, the main venue would be a hockey arena. The dress code for the gala banquet was going to be flannel shirts and plans for the evening entertainment included street hockey.

But even great dreams must face reality, and in this case, it was the cold, hard facts of COVID-19.

The organizing committee of the International Snow Science Workshop (ISSW) scheduled for Oct 3–8 in Fernie, B.C., recently made the incredibly difficult decision to cancel the conference. Thousands of volunteer hours have gone into organization and venue preparation, but with travel and gathering restrictions still in place, the choice is clear.

This is not the first time this conference has faced uncertainty. About a year ago, when COVID-19 was still a new reality for all of us, the decision was made to postpone ISSW to 2021 from 2020. After the Canadian Avalanche Association's very successful Virtual Spring Conference in May 2020, the ISSW committee recognized the potential for an online conference. Planning began quickly and that fall, the first ever Virtual Snow Science Workshop was held, with close to 1,200 participants signing in from around the world. The recorded sessions from that conference are now publicly available at VSSW2020.com.

To say we are disappointed is an understatement, but the health and safety of the conference delegates, our event volunteers, and our host community is a top priority. Since the notice went out to sponsors, supporters, and followers, we've had nothing but supportive feedback. The ISSW Steering Committee was especially encouraging, ensuring us that everyone was "uniformly sad to have missed the opportunity to experience ISSW in Fernie."

It's been quite the ride. We send our best wishes to the organizers of the next ISSW, scheduled for 2023 in Bend, Oregon, with sincere hopes that COVID is in our rearview mirror by then.

Flakes


That must be that new winter drone that uses computer modelling to calculate the current snow depth...
PIZZA
Nah – I just ordered a pizza.
©Buchanan


Wyssen Avalanche Tower
The most effective, reliable and time-efficient way to trigger avalanches remotely
This avalanche tower protects the Trans-Canada Highway in Yoho National Park