NZ AVALANCHE DISPATCH

JUNE 2021

WORKPLACE STRESS INJURIES

IRENE HENNINGER

KEVIN BOEKHOLT

INTERVIEW

TERRAIN AND DECISIONS

DR. JORDY HENDRIKX

Proudly Partnered

OUTDOOR SAFETY

NEW ZEALAND MOUNTAIN SAFETY COUNCIL

Pete Oswald shreds the East Face of Aoraki/Mt Cook as part of a full ski descent. Photographer: Neil Williman

In this Issue

On the Cover

Features

Community

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.

Page 86

FIND US HERE

Feature Contributors

Irene Henninger currently works as an Avalanche Forecaster for the Northwest Avalanche Center in the United States. In New Zealand, she has worked as a ski patroller at several ski fields in the Craigieburn Range and as Snow Safety Officer at The Remarkables.

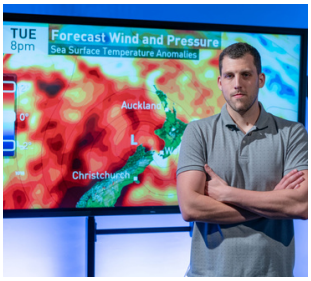
Dr Leighton Watson is a postdoctoral scholar at the University of Oregon - although currently stranded in New Zealand due to COVID-19. He uses geophysical observations (seismic waves in the earth and acoustic signals in the atmosphere) to study natural hazards such as volcanic eruptions and snow avalanches.

Jordy Hendrikx is the Director of the Snow & Avalanche Laboratory in the Department of Earth Sciences at Montana State University. He has spent the last 20 years working on snow and avalanche projects in the mountains around the world, from Antarctica to the Arctic. His most recent work focuses on ways to think about risk, considering terrain, human-dimensions, and decision making.

Frank Techel has worked since 2011 as an avalanche forecaster at the National Avalanche Warning Service in Switzerland. Before taking up this position he worked in various positions in ski area and highway snow safety programmes in Switzerland and New Zealand.

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 and decisions under uncertainty.

Susanne Wahlen is head of Monitoring Solutions at GEOPRAEVENT, a company specialized in alarm and monitoring systems for natural hazards, based in Zurich, Switzerland. Susanne Wahlen holds an MSc in Climate Sciences and a Postgraduate Diploma in Risk, Disasters and Resilience. She has worked globally with measurement and instrumentation technology and now focuses on customized monitoring solutions."



Ben Noll is a meteorologist with NIWA's weather forecast team. Based in Auckland, Ben leads the team developing NIWA's Seasonal Climate Outlook: (https://niwa.co.nz/climate/seasonal-climate-outlook) - a monthly outlook which covers expected weather patterns for the three months ahead.

Will Rowntree is an Aspirant Mountain guide with the NZMGA and Snow Safety Officer at The Remarkables. Will is passionate about talking passionately about the industry and not reaching conclusions. He enjoys taking skis for long walks in various National Parks.

Mads Naera was born in Denmark where his meteorology career started at the Danish Meteorological Institute. He has been a forecaster at MetService since 2001, where he is on the Severe Weather team, issuing warnings and watches and responsible for snow forecasting. Surfing and skiing - and thinking about surfing and skiing - take up most of his free time. That, and taking his dog for runs.

Markus Landrø, IFMGA Mountain Guide. Leader of the observer network of the Norwegian Avalanche Warning Service. He is currently finalizing a Ph.D. on decision-making in avalanche terrain at UiT The Arctic University of Norway.

Aubrey Miller teaches and conducts research in geospatial science at the University of Otago National School of Surveying. His interests and background are in GIS, natural hazards and outdoor recreation. Prior to relocating to Dunedin, he worked for the US Forest Service in Colorado, USA doing recreation planning and management. Aubrey is currently working on a PhD that blends his interests in snow avalanches and geospatial modelling to prepare for extreme events in New Zealand.


Chill
WWW.CHILLOUT.NZ
SNOW SAFETY
& TOURING COURSES
RUN BY ANNA KEELING GUIDING, HANDS-ON AVALANCHE AWARENESS
& BACKCOUNTRY SKILLS FOR SKIERS & SNOWBOARDERS.
BOOK NOW FOR 2021
explore@chillout.nz | 03 365 6530
Anna Keeling
Guiding

Alan Lelieveld

Atiamuri legend Alan lelieveld has been working and traveling in the snow industry for a decade and a half. Inspired by the alpine settings he works in, Alan has developed some badass photography skills and parlayed these into a marketing and content creation position at porters ski area. In this issue we feature some of the amazing images Lelieveld has collected over his many snowy seasons ...

How many days a year do you spend on snow?

Pre-covid 200+, now 100

Where have you traveled for work?

Canada, Sweden, Japan, Austria, Norway

What was your favorite place you traveled to and WHY?

Japan, pow

How much time do you spend on the back end?

If it's something I really like, maybe 30 minutes.

How do you know when you are "done" with a photo?

Depends on the desired look, it's easy to overdo it, so sometimes less is more

What inspires you in your artwork?

Mountains, snow, friends

Where do you see your photography in 1 year? 5 Years? 10 years?

FPV drone follow cams. All about drone piloting and landscape photography

What makes a good photo for you?

For me it's about trying to bring the viewer into the setting and allow them to connect with that unique moment in time. The winter months provide the most inspiration for me and the combination of low angle natural light matched with pow is my favourite setting to shoot photos in

Anything else you'd like to mention?

Shout out to Ullr, please try harder this winter

Spraying the Man-Pow. Not exactly the picture of winter... but where would NZ skiing be without some good ol' human-made product?.

When it looks like this in the Castle Hill Villagio, you know its time to get ready for some epic riding! This one ended up being 100 cm+ followed immediately by 50 mm of rain...

Sweden. waking up to this out the kitchen window...

Porter Heights and Crystal Valley...no place I'd rather be

Kea! (with Longframe)


Black Diamond
LIVE.
SKI.
REPEAT.
Jetforce Pack
Reacon
Beacon
Transfer 3
Shovel
Quickdraw
Probe
[JIM YOUNG, GAMACK RANGE, AORAKI MOUNT COOK]
Find a stockist: southernapproach.co.nz
southernapproachnz
Photo Credit: Allie Rood Insta: @allieoutside

Moose and Co. styling the 'Mainline' in Crystal Valley, southern Craigieburns.

Porters Heights, the Southern Craigieburns and the Porters Valley after a storm

Kia Ora Everyone!

The goal of the *NZ Avalanche Dispatch* is to provide an information sharing platform for the snow and avalanche safety community of New Zealand. One year on we feel like we are steadily achieving that goal. We would like to say a huge ***Thank You*** to all of our readers and everyone following us on social media, as well as to all of our contributors over the last three issues. We could not have done this without you.

We also want to thank our new sponsors for 2021. Some fantastic businesses here in New Zealand and overseas have stepped up and helped out the cause this season. When you see these businesses advertisements in the magazine please support them as they have supported the New Zealand safety community. Without our sponsors we cannot produce the magazine nor can we make the improvements we want to make to the *NZ Avalanche Dispatch* in the future.

Speaking of improvements, we have some cool new initiatives coming soon:

We are very pleased to announce The *NZ Avalanche Dispatch* is officially *going to print!* High quality paper copies of the *NZAD* are now available for wrapping fish, starting fires or even reading with an expensive micro-brew at your side. To pre-order just email us at nzavydispatch@gmail.com with the number of copies you want by June 18th. There is nothing better than the feel of a real paper copy in your hands.

Secondly, we are upgrading our publication on *ISSUU.* This will mean greater access for readers and a downloadable PDF version of the magazine. Look for this change coming soon.

This issue is packed with features, news, photos and everything else you expect from the *Dispatch*. Our September Issue is already in production. If you have any ideas for stories, a great photo you really want to share, or anything else please do get in contact. The door is always open and we would love to hear from you!

Thanks again to all our readers, contributors and sponsors. We cannot do it without you and appreciate all your efforts! We are always trying to build our readership both online and off. Please help us spread the word by sharing our content on social media or by simply talking-up the *NZ Avalanche Dispatch* to friends and family.

Have a safe winter and we will see you all in September!

Cheers - BC

Cover Shot

Front Cover: *A groomer works on the upper T-Bar track at Porters. Image by Alan Lelieveld*

Managing Editor
Brad Carpenter

Editor
Caitlin Hall

Contact

nzavydispatch@gmail.com

Proudly Partnered

OUTDOOR **SAFETY**

NEW ZEALAND MOUNTAIN SAFETY COUNCIL

Remembering a legend: Trev Streat

On September 28th 2020 there was a moment of silence in the mountains across the world. Trevor Streat was known as a legendary guide, avalanche forecaster and all round great guy, who passed away on this day after an arduous battle with cancer.

Trevor Streat, affectionately known as "Trev" joined Alpine Guides in 1993 after several years working for Harris Mountains Heli-Skiing. While he did some stints in Methven, and regularly worked overseas in India and various other locations, the bulk of his guiding was done at Mount Cook with Alpine Guides and this quickly became Trev's patch.

Kevin and Trev Streat 2019 Leibig Range Mt Cook Heliski.

Trev became a full IFMGA guide and worked in both climbing and skiing. His main passion was heli-ski guiding and it wasn't long before he became director of the heliskiing operation. He was the master of the Mount Cook region as he knew each area like the back of his hand, meticulously in tune with the weather and snow conditions alike. Lots of learning, occasional close calls, endless powder turns, and many happy guests followed through the years at Cook. Trev was a true mentor to the guides he worked with and became somewhat of a "rock" to those around him at Mt. Cook. He was someone that everyone could look up to and learn something from. At a winter training after a few drinks, Trev's now famous statement to the new guides was, "It's the most fun, most rewarding job you will ever have in your life! I struggled to get a start but now I'm in, I realise it's the best thing I have ever done."

Trev became truly respected in the industry both locally and globally, working within a particularly small industry he was well liked and sought after. He was the main avalanche forecaster at Mount Cook since the program was initiated, a role he never tired of and always delivered quality forecasts for. In recent years Trev took on a coordination role for the Mountain Safety Council where he was responsible for overseeing the quality of other forecasters work as well as providing technical support for the program. His input into the NZAA has had a significant influence in achieving the quality product we now have today.

Trev was one of New Zealand's most experienced avalanche practitioner's, although he wouldn't admit to this - if ever questioned he'd quickly divert to his favourite line "I just want to go skiing". Trev made a huge contribution to the avalanche industry in NZ through his contributions to the NZAA program, not to mention a lifetime of sharing experiences, skills and mentoring others. We will continue to tell Trev's stories as we navigate the mountains without him, remembering the many grand stories and trips he shared with those who were lucky enough to know him.

-Kevin Boekholt

HEALING TOGETHER

A PROGRESSIVE PERSPECTIVE ON STRESS INJURIES

BY IRENE HENNINGER

Several years ago, while working as a ski patroller, I was unfortunate enough to experience a workplace fatality with a coworker who was killed in an avalanche. Since that tragic day, I have often dwelled on the emotional repercussions of accidents or near misses amongst outdoor professionals and rescuers. Awareness of stress injuries (known to many as PTSD) and employer assistance for these injuries is growing. However, many professionals still lack the resources and support they need to recover. While I claim no expertise in this field, my goal is to encourage awareness and grow support for people challenged by traumatic events. This is a reflection on my personal experiences, what I've heard from others, and thoughts on ways we can help people work through stress injuries.

After the avalanche fatality, the ensuing days, months, and years were challenging for all of us on our tight-knit team. At first, the crew was stunned. Upper management visited us and offered small amounts of support for the next two days via baked goods, a pamphlet on counseling, and a quick visit from the local chaplain. Management was doing what they thought was best, but emotionally in the long run it was nominal. Clearly there was no plan, and several extremely important steps to initiate healing were missed. After a week we were told to forget about it and move on. Everyone outside of those of us on the team, close friends,and family forgot about it. Looking back I cringe when I think about how badly the situation was handled and how many members of our community struggled for years without psychological healing

In an effort to better understand stress injuries in the avalanche industry I recently conducted an informal survey of professionals from across the industry in New Zealand, Canada, and the United States. I spoke with highway forecasters, public forecasters, ski patrollers, guides, and search and rescue. I received a range of responses on how their organization reacts following a traumatic accident. Many of the professionals said that their employer had a plan. You're allotted days off. You can have assistance with getting a counsellor. One organization does a critical incident stress debrief and provides a counsellor. A rescuer told me their team has support dogs, mental health experts, and they consistently follow up with each other after an incident. On some occasions the organization would bring in a guest speaker. This organization deals with several body recoveries a year and clearly that's made them more dialled in in terms of emotional support.

At the other end of the spectrum, I heard from a few that just getting together with mates and a choice beverage at the pub is how they work through their stress injuries. Out of my coworkers, the ones who I saw struggling the most took that approach. This old school technique has been replaced in recent years with more progressive ideas about counseling and organized debriefs. Empirical evidence indicates that this tends to be associated with better outcomes for people suffering from a traumatic stress injury.

While patrolling in 2010 I suffered a traumatic brain injury (TBI) on the job. It took me five years to realize that, despite everyone thinking I was "all good", I had been struggling mentally for years after my accident. Since then, I've spoken with others who've had serious head injuries and faced similar hidden challenges for years after they physically recovered. Reflecting on our experiences many of us found that we failed to recognize that we are in a rough emotional state when we are suffering the most. These realizations usually would only occur long after, if at all.

It was eerie seeing first-hand the parallels between TBI's and stress injuries and how they appear to affect the brain in similar ways. As with my TBI, after the avalanche incident I saw coworkers getting unusually angry, sad, or frustrated. Many struggled emotionally with workplace disagreements, and other social aspects where they normally would excel. These emotional responses affected both their jobs and their personal lives and are textbook for stress injuries. At the time, if you were to suggest that their frustration stemmed from the incident, denial would often result. Stress injuries are sometimes not things that people can help themselves with, and many struggle to even acknowledge their presence. Many sufferers of stress injuries need active outside influences to help break down the barriers. One patroller from my survey told me their team had mandatory counselling after a fatality. That may sound a little extreme, but it might be the only way for some people to begin to heal.

Nowadays most workplaces have health and safety obligations when there's an accident. You report what happened and what to do to avoid it happening again. These are usually for tangible damages (people or equipment) but there's also an emotional component that often goes overlooked. Debriefs, from both a logistical and psychological standpoint are an excellent start for initiating the healing process. It is also important to keep in mind that people who were not directly involved in an incident may be struggling as well, so consider including them.

Many of us in this industry live and breathe a lifestyle that is very different from most people. The outdoors and mountains embody us. However, this culture has also fostered an awkwardness around the idea of speaking with a counsellor "they don't understand us, and what we do". While this concern is valid, there are councillors with experience in traumatic stress injuries in an outdoor setting that may be a better fit. Perhaps if we sought them out and fostered relationships with our companies and organizations before we needed them, we may be better equipped for the next traumatic stress injury. There are mental health experts out there who do run around high in the mountains- let's get a resource list going!

A great example of this is the American Alpine Club's Climbing Grief Fund that has gained a lot of traction in recent years. It focuses on grief and trauma in the climbing, alpinism and ski mountaineering community, connecting individuals to effective mental health professionals and resources. The work of the Climbing Grief Fund has made an excellent blueprint for us to use.

While all of us in the avalanche industry are familiar with the inevitability of fatalities and trauma, it is important to keep in mind that there doesn't have to be a fatality for an event to cause a stress injury. Many people are affected by near misses and other close calls. Having a plan and knowing the steps to take afterwards is key. As an employer, be sure your employees know what's available to them and what they can do to help their mates. Encourage people to check in regularly with each other after an accident. Find a local counsellor that your team can relate to and that can be called on when things go pear-shaped. As an employee or volunteer, encourage your employer to have a plan.

A few years after my colleague's avalanche accident, the healing process began for the team. There were open discussions for the first time, and emotional health became a welcome topic in safety meetings. By changing the workplace culture we allowed the recovery process to begin.

My perspective on traumatic stress injuries comes from a career in outdoor recreation and is largely focused on the workplace. However there are many concepts which can be translated to recreational accidents in the mountains (or anywhere) as well. I hope it gets you all thinking about how you can make improvements to your personal wellbeing and those of your teammates. With the intricacies and nuances of each team and situation, there is no cookie-cutter approach. But I think we can all agree that we are stronger speaking together as teammates than in silence by ourselves.

The following resources may be helpful for learning more about managing and recovering from traumatic stress injuries:

Hone, Lucy. What Abi Taught Us. Auckland, NZ: Allen & Unwin, 2016

The Avalanche Hour Podcast, Interview with Jake Hutchinson (Ep. 3.3)
https://soundcloud.com/user-23585762/the-avalanche-hour-podcast-33-jake-hutchinson

Sharp End Podcast - Psychological First Aid (Ep. 34)
https://soundcloud.com/the_sharp_end/psychological-first-aid-ep-34

5 Components of Psychological First Aid
https://blog.nols.edu/2017/05/22/5-components-psychological-first-aid

Stress Injuries and First Responders
https://responderstrong.org/aiovg_videos/laura-mcgladreys-operation-green-stress-injury-series-video-1/

Mountain Safety Council 2021 Early Winter Update

By Tom Harris, MSC Partnerships Advisor-Alpine

We at the MSC are looking forward to what we hope will be an awesome winter, and we're sure you are too! As always, we are busy on a wide range of projects, so here's my round up of what's happening in the Alpine/Avalanche space for us right now. Happy reading, and best wishes for a great winter!

SHAC 2021

The Southern Hemisphere Alpine Conference (SHAC) 2021 took place recently (May 26-27 in Wanaka), and it was one of the best yet! Many of you reading will have been in attendance, particularly since this SHAC was our biggest ever and a sellout with 200 tickets for the conference days. We really appreciate the support for the event and hope that those who attended got a lot out of it.

At the time of writing we are preparing a survey for SHAC attendees to fill out. This will aim to gather a bit of info on what everyone liked and/or wished was better,

The 2021 SHAC venue in Wanaka.

so we can improve the next iteration of SHAC. I'd encourage any readers who attended to fill it out once you get it in your inbox.

Another development is that we organised for most of the presentations at SHAC to be recorded (thanks Pete Oswald for the help on this), and these will be publicly available to view shortly. So, if you missed SHAC, or know others who couldn't make it, or saw a presentation that you think your friends or co-workers would enjoy, this is a great way to get filled in on what happened in Wanaka. Stay tuned...

Despite effectively closed borders, we had a stellar lineup of presenters, and I'd just like to extend my thanks to them again for being so willing to participate. The next SHAC will be around May/June 2023!

NZAA/InfoEx

Over the summer, we were able to make some improvements to the NZAA website and InfoEx. Below are some highlights:

- New Public Observations page on avalanche.net.nz. Here you can now view public observations by using filters for region, observation type, and date range and view them in a table format. This should allow for more easy browsing of observations, particularly if you're just interested in those for a particular area or time period.
- Updates to the InfoEx map. Now you can see locations from across the country and can use a satellite map view. In addition, you'll see the observation name when hovering your selector over the location, rather than having to click it.
- Slight re-order of the Hazard Analysis print out.
- Some user experience improvements to the NZAA and InfoEx on a mobile device, particularly when using drop downs and entering data.

As always, if you have any feedback on the NZAA/InfoEx website, let me know. The more detailed you can be with your feedback the better!

Public Observations 2021

Our NZAA Public Observations competition is back for 2021! We will be running the prize giving in a similar fashion to last year, with 3 different categories of prizes:

- Grand Prizes – Random public observations will be drawn from the whole season (June-October) to win awesome prizes, including a Black Diamond Jetforce Avalanche Pack from Southern Approach!
- Monthly Prizes – A random public observation will be drawn from each month (June-October) to win great Black Diamond prizes from Southern Approach.
- High-Fives – Select observations that nail the brief will win a pair of Black Diamond gloves throughout the season.

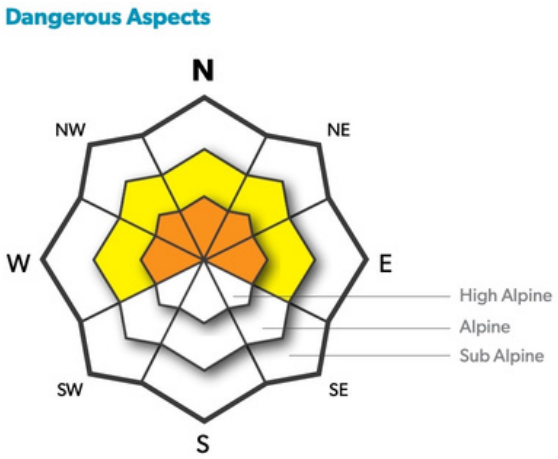
To be eligible to win, public observations must be submitted WITH A PHOTO. For more info, check out https://avalanche.net.nz/resource/competitions/ .

So, keep submitting public observations at avalanche.net.nz. Most importantly, it helps to inform your fellow backcountry users. The fact that you could win some awesome backcountry gear is just icing on the cake!

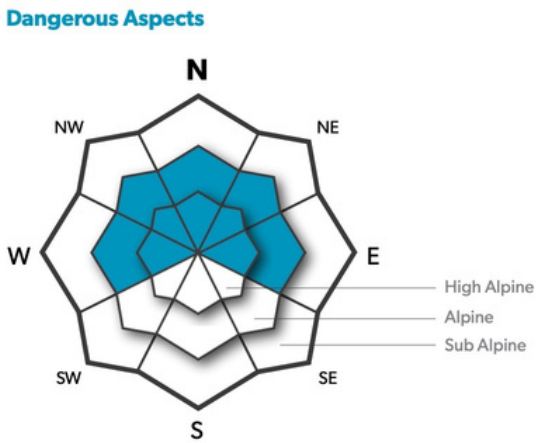
NZAA Avalanche Problem Danger Roses

Starting this winter, there will be a change to an important component of the NZAA public avalanche advisories, specifically the danger rose used for each listed avalanche problem. This change will simplify the avalanche problem message to the reader and better align with the framework the forecaster uses.

Until now, the danger roses for each avalanche problem have been used to show where an avalanche problem exists at various elevations and aspects in the region, while also applying a danger rating to these sections of the rose:



Starting Saturday June 5th, this danger rose will ONLY highlight where the avalanche problem exists ('area of concern' in blue) and will NOT apply specific danger ratings to the sections on the rose:



Danger ratings will still be used on avalanche advisories. There will still be an overall danger rating for each region, as well as danger ratings assigned for each elevation band. This change is ONLY for the avalanche problem danger roses.

For more information, follow this link: http://bit.ly/NZAARoseUpdate2021

Research: Avalanche Culture within the NZ Mountaineering Community

MSC, along with Research NZ and with the support of the NZMGA, NZOIA and NZ Alpine Club, is in the early stages of a research project that seeks to develop a clear understanding relating to the 'attitude and behaviour of the New Zealand mountaineering community towards avalanche dangers and avalanche safety'. This research, alongside statistical evidence, will be used to form the basis of improved avalanche prevention in New Zealand, specifically targeting mountaineers and alpine climbers.

MSC strongly feels that before evidence-based prevention initiatives can be developed a more comprehensive understanding of the target audiences' attitudes and behaviours relating to avalanches is required.

This research has been prompted by the statistic that 70% of avalanche fatalities in the past 20 years (19 of 27) have been mountaineers, an unusual statistic when compared internationally.

The research will consist of a survey that will go out to the wider mountaineering/alpine climbing community here in New Zealand over this winter. MSC has already selected a Reference Panel which will assist Research NZ in contextualizing and designing the survey. Interviews with avalanche survivors will also be undertaken to help identify possible survey topics.

Stay tuned for the survey when it opens this winter! If you climb in avalanche terrain or have in the past, then your participation will be crucial!

Avalanche Incidents in NZ Story Map

MSC has finished analysing and will shortly be releasing insights into avalanche incidents from 1999-2018 using ArcGIS storymaps. This platform allows the data to be viewed in a more natural fashion, and allows us to refresh the insights over time as we receive updated data. Once released, you'll be able to find this at: https://www.mountainsafety.org.nz/explore/avalanche-incidents-in-nz

SHAC 2021 Reporters

Our Volunteer Reporters Divulge their SHAC 2021 Learnings

Q1: What talk made the biggest impact on you and potentially your professional work?

Nicolas Cullen: Associate Professor, School of Geography, University of Otago.

I thought the conference programme that Tom Harris and the team from Mountain Safety Council put together was excellent, with the blend of science and more operational aspects of avalanche control related talks providing an enriching few days. The recent advances in the way people are observing seasonal snow struck me as being a big step change in the way we might address snow stability operationally in the future. The laser scanning that Simon Morris presented from Milford Road and the work being done at the Mountain Research Centre will likely open new doors in our understanding and management of seasonal snow in the Southern Alps and elsewhere. These new tools complemented with the type of avalanche hazard modelling being led by Aubrey Miller could really provide key insights to people like Don Bogie and others at the Department of Conservation who are currently responsible for developing new ways to assess risk from natural hazards using a threshold-type approach.

Cait Hall: Cardrona Ski Patrol and SHAC 2021 presenter, ARM level 6 student.

The talks that really resonated with me after the conference were Ryan Leong's on uncertainty, and Mike Lundin's on risk and avalanche control. I felt these were really applicable and great to get the cogs turning as we get started into patrol pre-season training and preparations, and even more so as we are adding new team members and new terrain to the ski field this season.

Ryan Leong: Whakapapa Snow Safety and SHAC 2021 presenter, CAA Level 3.

The talk that made the biggest impact on me this year was a presentation by Nico Fournier during the NZ Search and Rescue Seminar which ran the day prior to SHAC. Nico is the team leader for volcanology at GNS Science and his talk was about acceptable levels of risk with respect to sending people into potentially dangerous situations. The examples used were framed from a volcanic response perspective, but the concepts are readily applied to avalanche work. Having been in the hot-seat for the Whakaari White Island eruption response, Nico is well placed to share his learnings on this topic. The key points I took away were:

In this context, decision making requires two steps: Risk quantification, and a conversation about what is tolerable. Because the latter is subjective it is impossible to say what is "safe". The questions are; How do we quantify the risk for a given situation? How do we communicate this risk to a specific intended audience so that they can use this info effectively? How safe is safe enough?

These are questions - not answers. This wasn't a presentation about telling you what to do, but more concepts to be aware of and think about. Possibly one of the best and most refreshing answers of his was "Everything has gone out the window, the best I can say is it's a 50-50 call." It was refreshing to hear this level of honesty and reality, and from someone who is an international leader in their field.

Paula Roberts: Tai Poutini Tutor, ski guide and former Ski Patrol.

What a great 3 days the SAR workshop and SHAC was. I feel like I took something away from pretty much every presentation! Awesome to see it so well supported, and of course, the chats over beer are always a big part of it.

The talk that made the biggest impact on me with regard to my professional work was Don Bogie presenting on "Risk thresholds and Risk comparators from natural hazard risk".
This really got me thinking about 2 things:

- Communicating risk level to clients.
- Ensuring it is delivered in language they understand/relate to.

Sam Marsh: Porters Ski Patrol and current ARM Level 6 student.

Don Bogie's hazard matrix that he developed for DOC was super interesting. He had an interesting formula for assessing the level of risk involved for each DOC track/hut/activity etc, and each DOC track/hut/activity has a level of risk tolerance that it can meet, I was super interested to hear that they've even relocated huts that were in a location that exceeded their risk tolerance, I like to think that it will be possible to apply a similar system where I work at Porters.

Q2: What talk held the biggest surprise learning moment for you?

Paula Roberts

The talk that had the biggest learning moment for me was a tough pick.... But I have gone with Ryan Leong, presenting his "Dealing with Uncertainty".
For me, I now have some more tools to add to my toolbox. I feel that my intuition can be better explained and perhaps documented by incorporating natural uncertainty into the process. This will ensure that alongside knowledge source reduction, the process of dealing with uncertainty is more robust.

The last thing from me is around the really interesting science happening in the snow and avalanche modelling area and predicting the future of NZ seasonal snow. These fantastic projects have some great potential.

Ryan Leong

Scott Redwood's talk about the continuing evolution of the Milford Road program was also a good one. Seeing massive avalanches pound the road will always be awesome, but his insights into how they are now trialing a cheap (even by ski area standards) and readily available remote weather sensor to gather more data from zones where it was previously sparse was interesting. Sometimes it pays to think outside the box for solutions and this is a good example. A good light bulb moment for me.

Nicolas Cullen

Despite our advances in technology and ability to model snow and atmospheric processes, I was reminded by a number of the contributors that these methods can only at best complement hands on experience in many of the areas that our community are working in. The honesty and the manner in which the avalanche community reflects on their experiences is highly commendable, with Ryan Leong's and Roger Hodson's descriptions of their recent close calls a stark reminder of the hazards that people are sometimes exposed to. In particular, Ryan's description of that moment where he took a few extra steps up slope while doing avalanche control on Mt Ruapehu clearly reminded me that "gut feeling" and listening to and watching what is around you will never be entirely replaced by the tools provided by science.

Sam Marsh

Simon Morris' presentation on the Lidar system for 3D scanning the terrain surrounding the Milford Road is what I believe got the biggest reaction from myself as well as many people in the audience, the scan he showed us of a crown wall from a recent avalanche was super fascinating as it even showed the different types of snow within the face of the crown wall. The statistics involved were out the gate, if I remember correctly this system can take half a billion data points an hour, can scan up to 6kms away and has an accuracy of 15mm at 6kms, also the fact that there's only 3 of these scanning units in the world and one of them is on the Milford Road is awesome! Good old New Zealand!

Cait Hall

The biggest '*aha!*' or *wow!* moment for me was during Ana Keeling's talk reflecting on her research of avalanche involvements in Utah during Covid. I was surprised to hear that most people reported not being distracted by the ongoing pandemic. I was also taken aback with how many incidents were within ski areas that were closed because people felt "more comfortable" there even though no mitigation work was being conducted and it was essentially the backcountry, even though the ski area infrastructure was in comforting view...

WINTER 2020 – WHY DID IT SUCK?

BY MADS NAERA

METSERVICE SEVERE WEATHER FORECASTER

Last winter was a strange one. After the global chaos of Covid, and various levels of lockdown, I was probably not alone in looking forward to a winter of mountains and snow and clean air. Instead we got one of the warmest and least snowy winters, and many smaller ski fields never even opened.

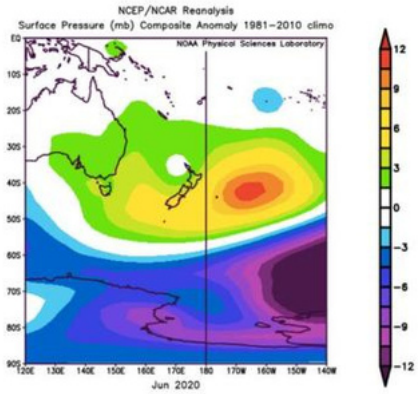
So what went wrong, and could it have been forecast? And what about 2021? TL;DR: Too warm in the North Island. Too dry in the South Island. But since nothing is ever simple or clear cut, let's delve a bit deeper:

For significant snow to form, we need cold air near the surface, and moisture aloft (specifically through the Dendritic Layer (around -12C to -18C). This can either happen during deep, cold, polar air outbreaks, or when moist, warm air from the NW is undercut and lifted by cold air from the south. Each of these scenarios brings different patterns of snowfall and quality - but that's possibly a topic for another article.

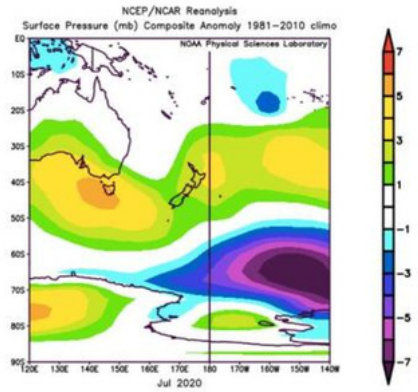
In 2020 the large scale (synoptic) weather patterns over New Zealand were very poor for snow, and sea surface temperatures around us too warm. For most of our winter, a pesky long-wave ridge of high pressure dominated the weather over southern NZ. The normal pattern of winter storms from S, SW and W never really became established, as the persistent high pressure kept snow-producing storms at bay.

These monthly pressure anomaly plots (right) for June, July, August and September 2021 showing higher than normal air pressure over southern NZ, except for August when some deep lows moved across the Tasman - unfortunately bringing warm air. Meanwhile, a succession of lows moved from the Tasman Sea across the North Island, bringing frequent bursts of significant warm rain.

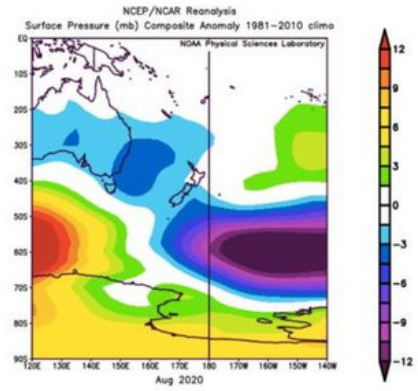
JUNE



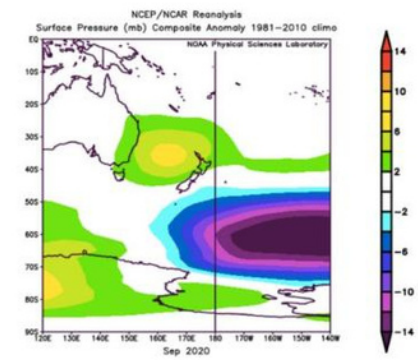
JULY

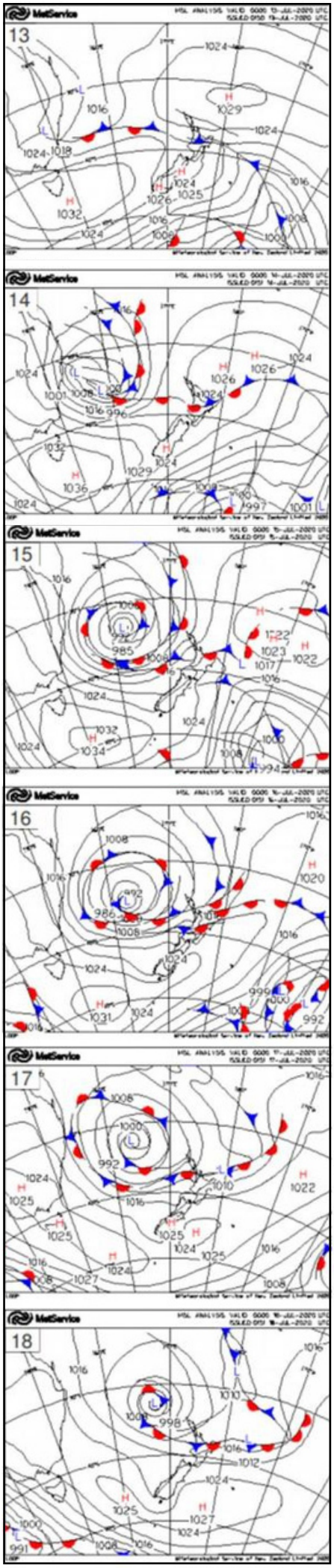


AUGUST



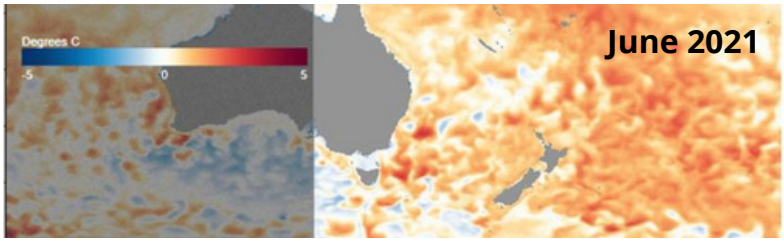
SEPTEMBER

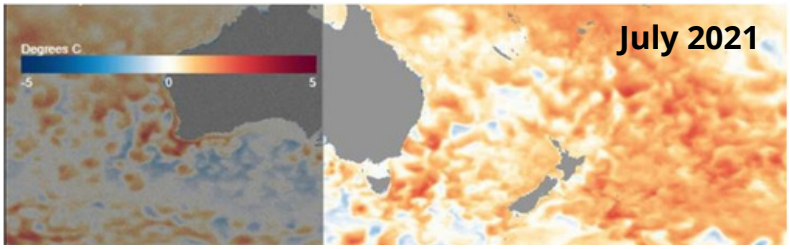


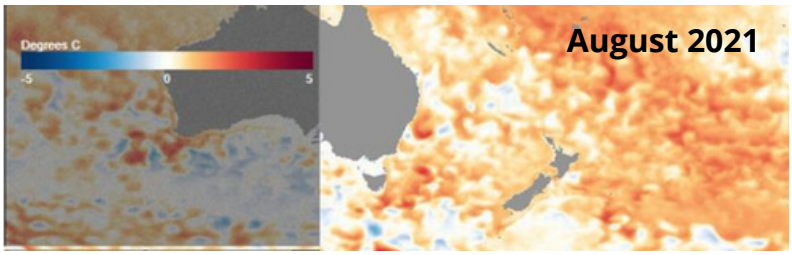


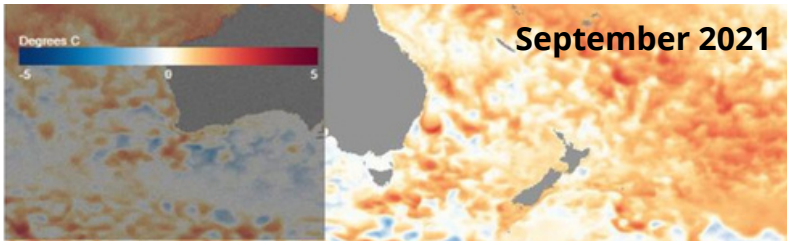
The sequence at left shows a good example of these patterns: a weak cold front brushes the east of the South Island, but the ridge soon rebuilds over the far south, while a large Tasman low moves onto the North Island. NSW gets massive surf, while the snow keeps eluding us.

Another factor was the higher than normal sea surface temperatures (see below) around New Zealand, making for slightly higher air temperatures. This is not necessarily an issue if there are sufficient cold air outbreaks, as the increased moisture can feed snow showers - as it happens over the Sea of Japan, and the Great Lakes in North America – but in dry, warm years it's a different story.



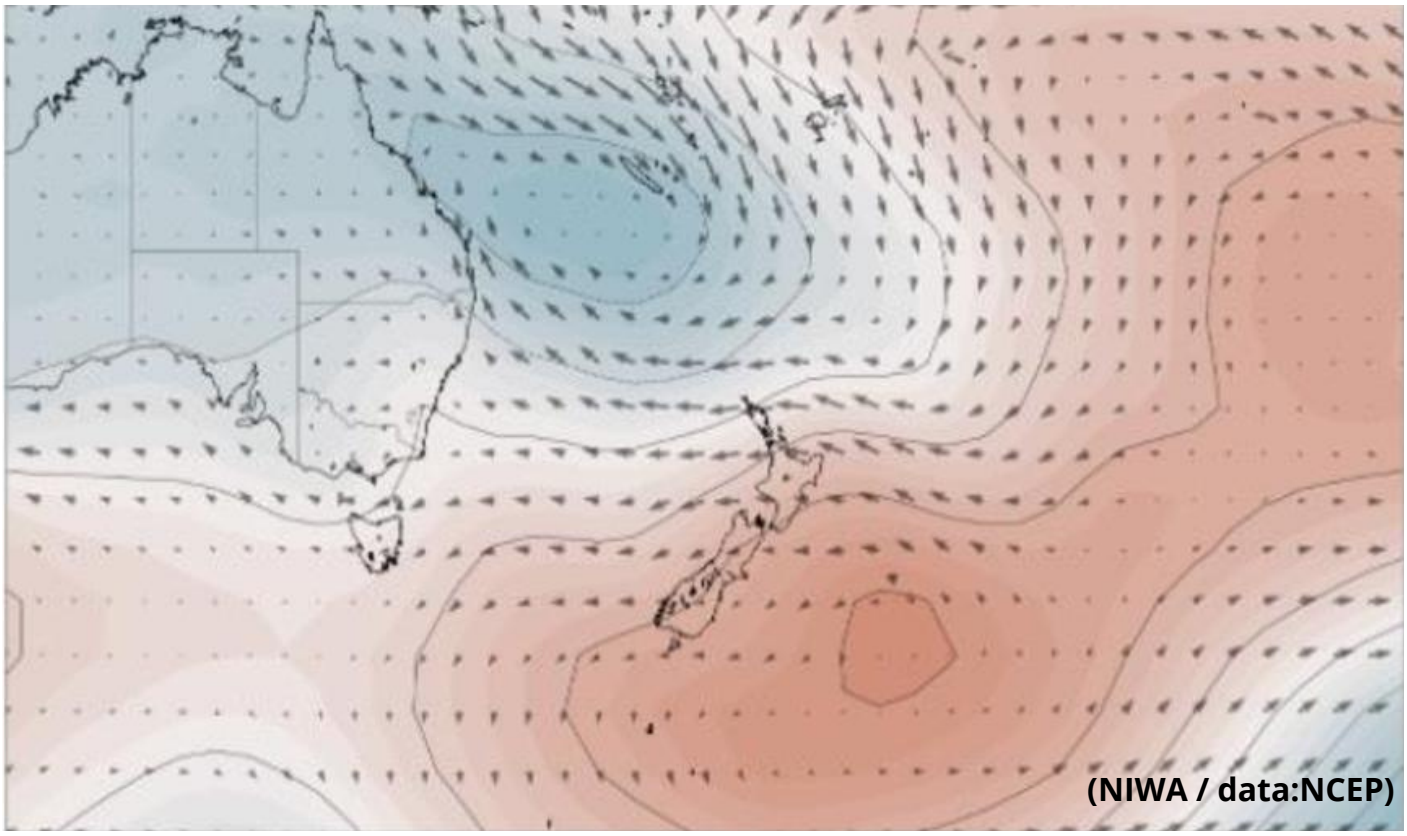




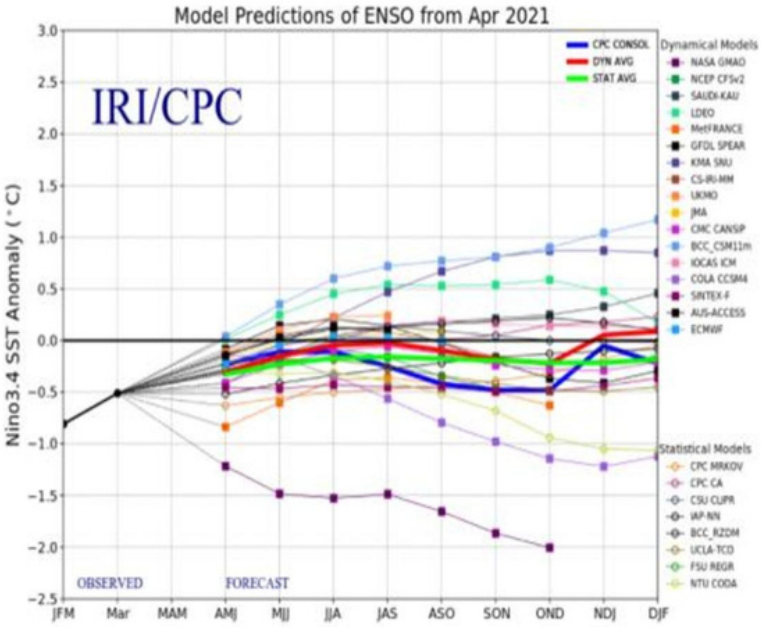


During autumn 2020 La Niña developed over the Pacific, strengthening through winter and spring. One of the main effects of La Niña in the SW Pacific is a weakening of the westerlies over NZ, often with easterlies in summer. In winter the south to southwest flow weakens.

Long term averages can often wash out significant features, but it is striking how similar this composite (below) of four La Niña summers is to the dominant winter pattern of 2020. Areas of above normal pressure are shaded in red while areas of below normal pressure are shaded in blue:



Whether the blocking ridge formed in response to La Niña, or other atmospheric drivers played a part is hard to say, but weaker than usual cold air outbreaks made no impact against the ridge. La Niña has been weakening through autumn 2021, and the forecast average is for a return to neutral phase this winter.



Seasonal forecasting is notoriously tricky, and not my area of expertise, but if you were to twist my arm, I'd say we're in for a more normal winter this year. Here's hoping!

NIWA predicting drier start for some areas this winter

Ben Noll - NIWA Meteorologist

Don't get too excited about early winter snowfall – that's the message from NIWA meteorologist Ben Noll.

"The outlook heading into the winter season suggests extended dry spells and periods of mild temperatures will continue to be a theme for New Zealand," says Noll.

However, while this isn't the ideal snow recipe, Noll says enthusiasts shouldn't despair.

"A well-timed cold snap and low-pressure system can bring a dump of snow that lasts for several weeks — even in a season that's drier and milder overall," says Mr Noll.

"Compared to last winter, weather events could be a bit more common in Canterbury, but longer dry spells will be possible in the south and west, including Otago and Southland."

NIWA's winter outlook was released online at the start of June, covering prevailing weather patterns from June-August.

Mr Noll says one of the first significant snowfall events for the Canterbury region occurred at the end of May. The low pressure system responsible, which also produced significant flooding, transported relatively warm, moist air down from the tropics. This meant that rain mixed in with snow at high elevations.

As seen in recent winters, relatively warmer temperatures have led to a higher elevation of the rain-snow zone.

Mr Noll says NIWA's forecasting team considers a wide range of 'climate drivers' when they carry out seasonal outlooks.

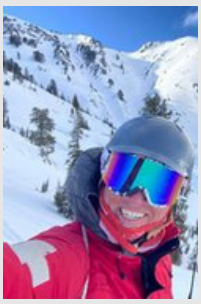
"We're essentially trying to understand who's at the steering wheel of Mother Nature's car. This process involves looking at ocean temperatures, atmospheric circulation patterns, and understanding how these climatic factors are predicted to evolve in the coming three months.

"Once an understanding of the broad air pressure pattern is established, an outlook of rainfall and temperature is provided for six different climate regions of the country. A seasonal outlook can provide information, in broad strokes, as to whether the next three months will be warmer, cooler, wetter or drier but can't predict whether your ski trip in August will come with bluebird conditions."

Despite the outlook, Mr Noll says it's still early in the season and there's still plenty of winter to bring flurries of snow. Astronomical winter begins in the Southern Hemisphere on June 21.

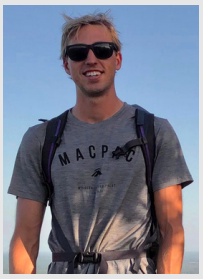
A mid-winter outlook will also be published in the next issue of NZAD.

New Positions in 2021

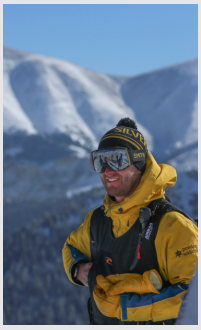


Hans Hjelde will be taking on the Snow Safety Officer role at **Craigieburn Valley Ski Area** this season. An experienced snow enthusiast, ski patroller, ski guide, and avalanche forecaster Hans has been fortunate to work in several unique locations with a variety of snowpacks - from Colorado, Alaska, Utah, and Nevada in the States, to Kashmir in India, and to Mt. Ruapehu on the North Island. He's looking forward to the upcoming season.

Llewellyn Murdoch will be assuming the 2IC Snow Safety position at **Treble Cone Ski Area** this season. Llewelyn has been working with the ski patrol at Treble Cone since 2013. Previous to patrol at TC, Llewellyn "learned the ropes" in the Craigieburn Range at Mt Cheeseman and Broken River Ski Area. Llewellyn has also spent 3 winters working in the mountains of Colorado for the Colorado Mountain School. In the summertime Llewellyn works as a rock climbing guide and instructor for Wanaka Rock Climbing.



Matt Jeffery will be the new Ski Patrol Manager at **Porters Ski Area** this season. Matt is one of a few Aussie battler's who have come across the ditch and found a career/life in the mountains. After graduating the TPP patrol course Matt has worked at Whakapapa and in Canada, before taking some time off during Covid to study paramedicine.



Carter Spencer has been obsessed with all things snow from an early age. His passion has taken him to Alaska, Japan, New Zealand, and Russia in search of the white gold. He cut his teeth guiding clients on the harsh continental divide of Colorado, U.S. As the Snow Safety Officer at **Mt Cheeseman Ski Area** this season, Carter brings over a decades worth of backcountry knowledge including six seasons cat ski guiding and five winters working in the club fields of New Zealand.

Luke Crow. has worked in the ski industry for over 20 years, starting by flipping burgers at the Remarkables. He worked as an instructor both here in NZ and overseas for quite a few seasons and moved into patrol in 2007 at **Cardrona Ski Area.** Luke has been there on and off ever since. This year Luke is moving into the Assistant Snow Safety role which he thinks will be a good challenge with a new role and also new terrain at Cardrona. Luke is looking forward to the position as, "I have a great team to support me and for me to learn from."

2020 Avalanche Risk Management Level 6 graduates

From left: Llewellyn Murdoch, Sam Bamford, Eathan Mikkelsen, Jimmy Armstrong, Olivier Cossette, Peter Bilous (Director), Jude Hawthorne and Jim Young (Instructor). Others to complete their study but not shown: Cameron McAlpine, Petrouchka Steiner-Grierson and Gideon Geerling.

Adventure Consultants to hibernate business

Due to the disruption to travel, brought about by the global Covid pandemic, Guy Cotter and Suze Kelly, owners of the world renowned mountain guiding company Adventure Consultants, have reluctantly made the decision to place the business into 'hibernation' for the time being.

Guy Cotter, Adventure Consultants Company Principal released this statement regarding the hibernation::

"The company will discontinue the promotion of the main bulk of our guiding and expedition services globally until a time when we can safely and reliably reintroduce them. We have been immensely thankful for our New Zealand clientele who have supported us through this past year but unfortunately the scale of costs to operate the business has far exceeded income levels. To that end, we will not be operating the business functionally through the winter months of 2021. We anticipate that we will return to normal operations once our borders are completely open to the rest of the world.

Moving Adventure Consultants into hibernation does not mean we are closing indefinitely and we will continue to accept expressions of interest for our future expeditions. We will not confirm participation on an expedition until we know the trip can operate successfully without travel disruption or risk to staff, guests or local communities. We are hopeful that operations will return to normal in 2022 and we will confirm with prospective expedition members when we are confident we can operate within acceptable parameters.

Once again, we would like to express our thanks to all those who have supported us and our team and guides through this difficult period."

Willows expansion brings new lift and new terrain for Cardrona Ski Area

Cardrona Alpine Resort has announced that lift-accessed skiing and snowboarding in their Soho ski area will become a reality later this year with the opening of the Willows Quad chairlift, currently under construction at Cardrona Alpine Resort and due to be completed in time for the winter season.

Willows Basin will be the first new major lift-accessed terrain in New Zealand since theopening of the Valley View Quad at Cardrona in 2012. 65 hectares of primarily intermediate terrain will be accessed from the top of the McDougall's Chondola through to the bottom of the Willows Quad.

Willows, magical terrain, magical movie.

Avalanche Dogs Search Sans Snow

Story by Lisa Jaggi

Avalanche dog teams training in summer...without snow? It's not only possible...it's important! Avalanches can occur any time of year, so being ready to respond with confidence isn't just about winter's first snow hitting the ground. To ensure our avalanche dog teams are operating at a high level all year round, training shouldn't stop when the snow melts!

2021 saw LandSAR Dogs getting its first Avalanche Summer Training Camp off the ground, or more accurately - off the snow. Fledgling pup partnerships such as myself and Echo, were joined by experienced dog teams, keen observers, and a highly knowledgeable "pack" of trainers, assessors, and volunteers in New Zealand's avalanche dog world, to tackle a rabbit riddled, and summertime snow-devoid Tekapo training ground, only a few kilometers from our brilliant 'Lake Tekapo Cottages' accommodation.

A mindset shift away from "summer time = time off" was the aim of the game! Through the guidance of our experienced trainers, we developed our understanding of how training can continue during the summer months without snow to dig in. We were asked to consider the steps of a search from start to finish, which highlighted that the "indication in snow" (eg. dig response) is only a fraction of the many steps involved.

Over the course of two days, we were put through our paces by both obedience and search focused exercises that could all be performed off snow. Fun was injected into obedience using some friendly competition, which saw the group bonding while we tackled/polished communication with our canine comrades. To a group of high prey drive dogs accustomed to working in a more sterile snowy environment, this Tekapo farm was literally teeming with furry distractions to step up the challenge

Next it was onto shaping a response in our dogs to "articles" or "surface clues" in a sans snow environment, where digging isn't possible. For those of us whose dogs don't willingly bark, building a passive response like a "sit" or "down", was the objective. The positive spin off for a winter snow setting? Articles are less likely to get disturbed by the dog when located, and therefore add more accurately to the bigger picture of avalanche site clues. Developing a search plan, sticking to it, or knowing when to adapt on the fly,

Lisa Jaggi and her dog Echo (trainee search dog team).

was also covered and of particular importance to a "rookie" team like Echo and I. Learning to use the wind to our advantage, recognising subtle changes in our dogs behaviour, and working the terrain efficiently appeared key towards having a successful outcome - and all of this could still be practiced in a matagouri and bunny-burrow decorated landscape.

It would have been easy to feel completely intimidated by this accomplished group of people, with seasoned ski patrollers, mountain guides, experienced and skilled dog trainers, operational handlers (past and present) and assessors making up the majority of the group...but I was blown away by how considered, helpful and encouraging everyone's feedback and advice was. It felt like we were part of a bigger team than just myself and Echo. They say "It takes a village to raise a child" - maybe "raising" an avalanche dog isn't that different? Thank you to all those that volunteer their time, energy and expertise to be a part of the amazing "village" that "raises" LandSAR avalanche dog teams in New Zealand.

Paws crossed for a stellar winter - bring on the snow!

Land SAR Search Dogs Avalanche – Tekapo Summer Training Camp.

Court date set for U.S. snowboarders who triggered avalanche

Sources: AP news and Colorado Sun

A rare U.S. court case that some worry could deter other skiers and snowboarders from coming forward to report avalanches out of fear of costly retribution is about to begin in Summit County, Colorado. Tyler DeWitt, 38 and Evan Hannibal, 26 will go on trial on June 7th 2021 to face reckless endangerment charges in connection with the pairs involvement in the triggering of a large and destructive avalanche on March 25, 2020 near the Eisenhower-Johnson Tunnel of Interstate 70.

The experienced backcountry snowboarders weren't injured, but the avalanche buried a service road in about 20 feet (6 meters) of snow and came dangerously close to Interstate 70, a major route for ski traffic. As soon as they were safe, the two men called 911 to report the slide.

The slide, which was about 122 meters wide and ran about 366 vertical meters, destroyed one of six O'Bellx avalanche mitigation units in the area. DeWitt and Hannibal didn't immediately realize the slide destroyed the expensive avalanche mitigation system.

The two handed over video of the avalanche to the Colorado Avalanche Information Center and spent two hours at the scene describing what happened. . Eventually their video was handed over to law enforcement. That video eventually prompted state prosecutors to seek $168,000 in damages.

The area that DeWitt and Hannibal were traveling within was open to public travel and is an area popular with backcountry users. Backcountry enthusiasts and avalanche prevention specialists will be closely watching the trial, which was set to begin March 29, 2021 but was rescheduled because not enough jurors could be seated.

Denver attorney Jason Flores-Williams, himself an avid backcountry skier, is defending the two snowboarders and had this to say, "If you do everything that you need to do, they still might try to come after you and financially cripple you. That is the implication of what a guilty verdict would mean here, is it would send a message to everyone that the backcountry is now subject to prosecution. Our goal is to defend the backcountry."

What began as a small slide of a few inches of fresh snow stepped down to a weak layer and ultimately scoured the ground in the March 25 avalanche involving two snowboarders who are facing charges of reckless endangerment and fines to replace a damaged avalanche mitigation system. (Provided by the Colorado Avalanche Information Center)

Report sheds little light on fatal Alaska helicopter crash

Sourced from AP News Reports

A preliminary report from the federal agency investigating the fatal helicopter crash in Alaska that killed five people, including the richest man in the Czech Republic, sheds little light on the cause.

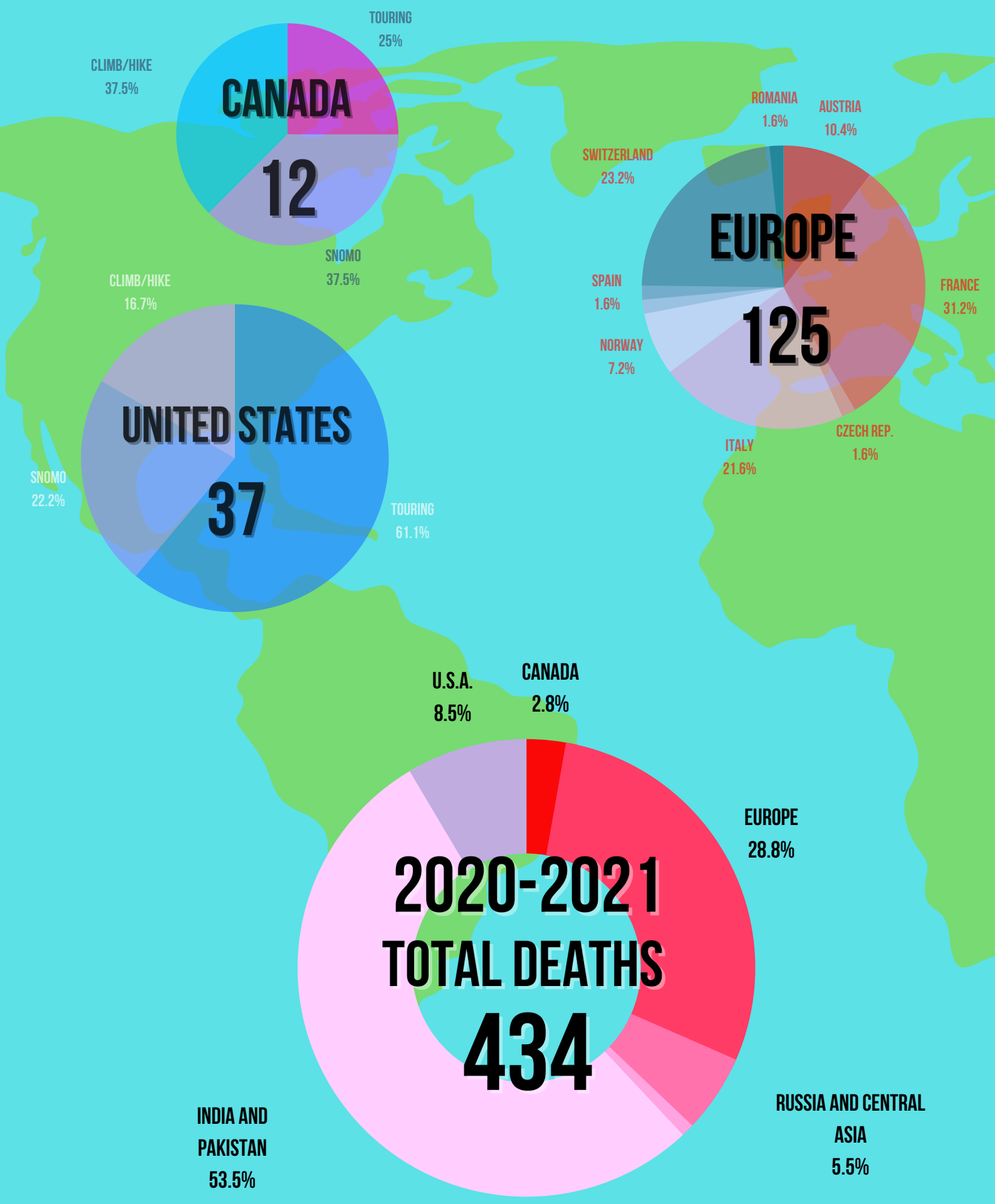
The Tuesday report from the National Transportation Safety Board said the helicopter involved in a heli-ski operation in the Chugach Mountains just north of Anchorage flew multiple legs on March 27, transporting the skiers to several starting points near Knik Glacier.

Data obtained from a handheld GPS unit shows the helicopter started another trip at 6:27 p.m. on a northwest heading, climbing to about 5,900 feet (1,798 meters). Six minutes later, the helicopter began to go over a ridgeline at 6,266 feet (1,910 meters), traveling at about 1 mph (1.61 kph). "The helicopter maintained a low altitude and groundspeed as it maneuvered over the ridgeline for the next few minutes," the report says. The data ended at 6:36 p.m., near the final resting point of the main wreckage. An NTSB investigator surveyed the site the next day by air and said the helicopter hit the mountain about 15-20 feet (4.6-6.1 meters) below the ridgeline before rolling downhill about 900 feet (274.3 meters) in rugged terrain and snowy conditions.

The weather conditions at the nearby Palmer airport were clear with visibility of 10 miles (16 kilometers) and gusts up to 6 mph (9.7 kph) mph.

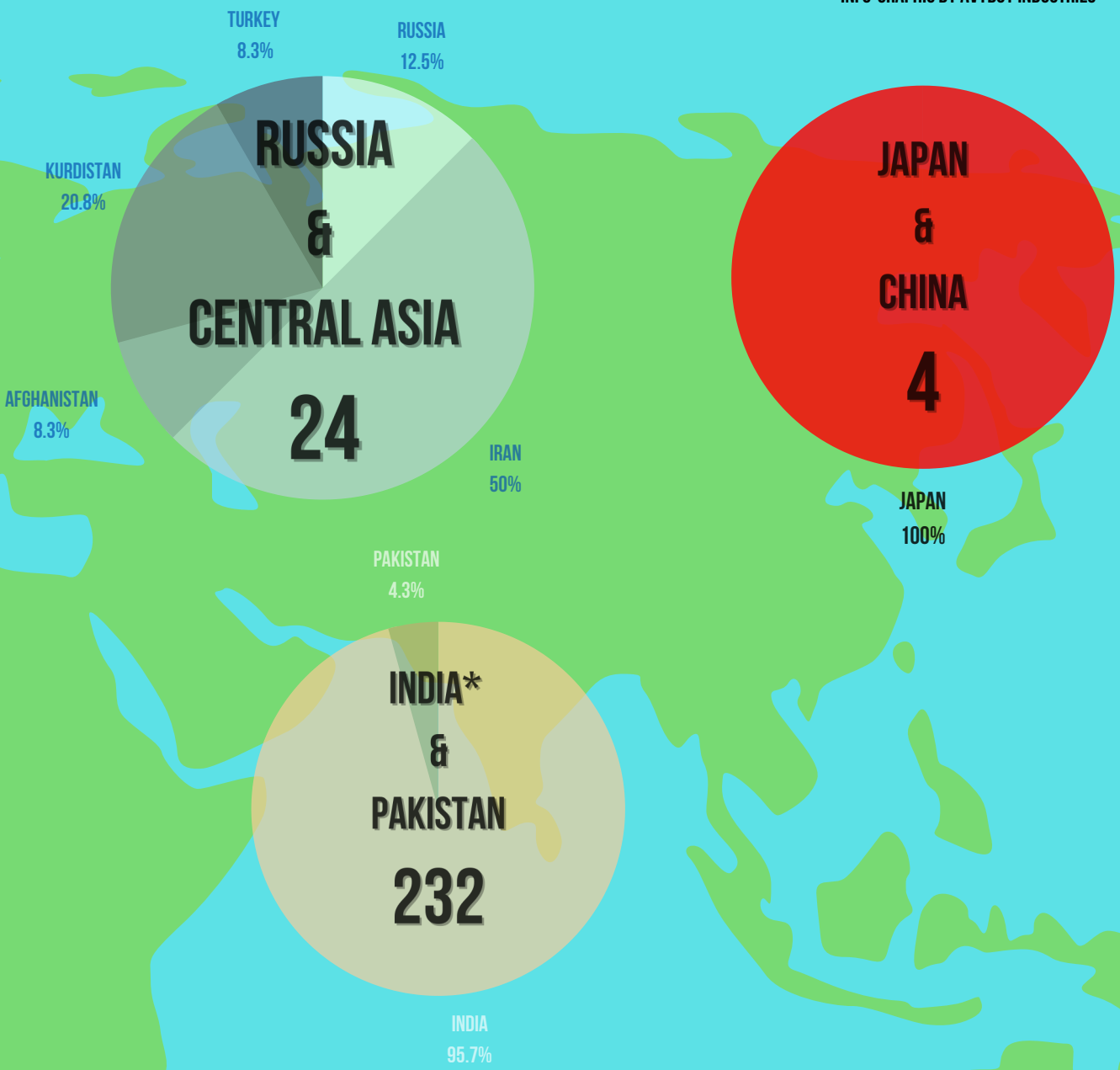
Killed in the crash were billionaire Petr Kellner, 56, and Benjamin Larochaix, 50, both of the Czech Republic; guides Gregory Harms, 52, of Colorado, and Sean McManamy, 38, of Girdwood, Alaska, and Russell, 33, from Anchorage. There was one survivor, David Horvath, 48, of the Czech Republic, who has spoken to federal investigators, the Anchorage Daily News reported. A final report on the accident, which should include probable cause, is expected within a year.

NORTHERN HEMISPHERE AVA



LANCHE DEATHS 2020-2021

INFO-GRAPHIC BY AVYBOY INDUSTRIES



*Estimated 205 deaths related to Tapovan Vishnugad flood/Nanda Devi glacial avalanche event (Feb. 10, 2021).

ONE SLIGHTLY H

ECTIC AFTERNOON

A NEAR MISS IN THE NORTHERN ALPS OF JAPAN

BY WILL ROWNTREE

This article first appeared in the NZAC The Climber magazine.

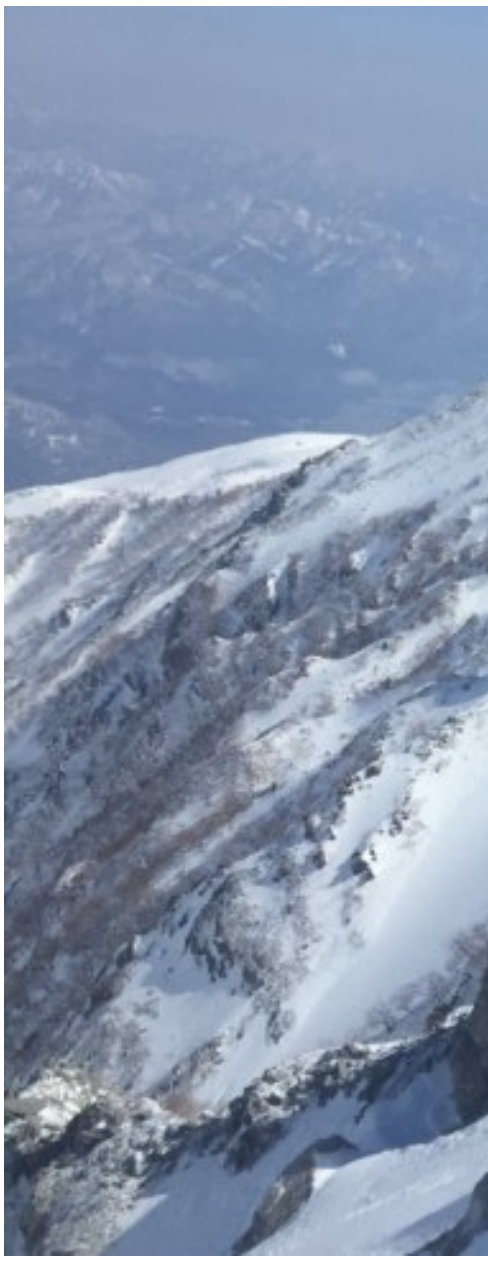
February 2020 Japan.

I have been working the winter as a ski guide in Hakuba, deep in the Japanese Alps. Truly a skier's paradise, there's everything from steep technical ski mountaineering to mellow, perfectly spaced tree runs. With the day off and a meagre 30cm overnight, Lewis and myself make rough plans for an afternoon ski tour in an area known as Hiodori. The weather forecast is for cold temps, calm winds, and intermittent cloud lingering around the tops. The recent snow has come out of the west with moderate winds. We have forecast a Considerable hazard of Size 1 – 1.5 Storm Slabs on steep and unsupported pieces of terrain on North through Easterly facing slopes. It's the first opportunity we've had to ski together, and we're excited to ski some great snow without guests.

Our main objective is a 35-40 degree NE facing slope of challenging to complex terrain. Based on our forecast the exact place where we would expect a hazard. Aware of this we discuss a plan to manage the terrain we are happy with and identify multiple other slope options with a lower level of hazard if things are worse than forecasted. In Japan if you do not go skiing on a considerable hazard you won't ski a whole lot and with the Storm Slab problem, we are comfortable that we can manage the hazard. We start off with a mellow skin up a summer road, before threading through some tight trees, towards a sub peak that marks the beginning of our descent. Along our ascent we gather lots of great first-hand information from Northerly facing aspects along the way. Plenty of cornice kicking into steep start zones and some hasty pit data indicates a good bond between the old surface and the new storm snow. We are pleasantly surprised and confidence in our objective increases. We reach our transition point and ski down to the top of the slope and in doing so make a slight change to a more NE facing aspect.

At this stage we discuss the plan of descent and I get ready to execute a ski cut. This is something I almost always do before committing to a line. I verbalise my entry and exit points and discuss the size of avalanche

expected and the run out. I barely touch my skis to the slope and the whole path avalanches wall to wall, a healthy size 2. The crown wall is 20-40cm deep and the failure propagated the full width of the start zone (50ish metres) with a rather light trigger on one of the lower angle areas of the slope.



I mutter something along the lines of "well that's f***ed" as this result is both unexpected and a significant result. I turn to discuss options with my partner. He tells me he is going to ski down to get a better view. I agree, and he goes to ski across a relatively small slope around 30-35 degrees in angle towards me. I'm looking away when he yells and I turn to see a blue and orange beanie rapidly accelerating downhill amidst a shattering slab of snow. Shit. The situation has escalated rapidly. My transceiver is out quick smart and I ski down the bed surface beeping away. I am relieved to find him perched on a tree just out of sight. Despite getting bounced through some trees he is ok. Where he stopped has prevented a horror ride through a steep and vegetated runout that would have been of high consequence. Our phones immediately start ringing (it is essential to have cell signal in Japan and we mitigate interference by keeping distance between cell phones and transceivers) and we look at each other, both thinking how do the guys at home know what just happened?

We receive word that a kilometre up valley, on the same aspect as ours, a party of 3 has triggered a size 3 with one person fully buried. The initial info is that the person buried has no transceiver. Word has gotten out quickly and people at home are concerned we are involved. We do nothing to settle their nerves by saying "Oh don't worry ours is a different avalanche." The reminder of other people in the valley triggers a thought of potential people below our slide path. Picking our way through the debris from the initial ski cut we clear the site of any transceiver signals. Glad that we are both ok and haven't buried anyone, our mood quickly shifts to kicking ourselves for letting this occur and we plan our exit out of the area.

To try and get to the rescue to help would've exposed us to just over a kilometre of complex overhead hazard. Unable to be of any assistance with the burial nearby we begin our egress out of the area towards a small ski field one valley to the North. A helicopter works hard to get rescuers into the other zone between intermittent clouds. It is mentally hard knowing a full-on rescue is occurring and that the likely outcome is going to be someone dead. It's not long before we encounter another group of tourers who, surprise surprise, have also been avalanched on a NE asp. Luckily no one is hurt, but they are recovering their gear and intending to ski down complicated terrain of the same angle, aspect and elevation... We are amazed at their nonchalant attitude and fill them in on the situation in the area. I encourage them to change their route but to no avail. After they disappear towards the potential afterlife, we bushwhack to a summer road and promptly head to the bar for a debrief.

What was expected to be an enjoyable afternoon had turned into a near miss for us. We later found out that the person buried had not turned their transceiver on but unbelievably was found alive

after 2 hours by a probe line. Being avalanche professionals we felt more than a little stupid that we had come that close to a serious incident. The following is an analysis of the mistakes I believe we made as well as the good decisions.

Our forecast prior to leaving home was thorough but informal. Our familiarity with the terrain and snowpack most likely lead to a more relaxed approach. We did not place enough significance on the change in aspect, in Japan the distribution of an avalanche problem is often widespread and as a result we put too much faith in the info gathered from the direct Northerly aspects. The biggest mistake I believe we made should have been the most obvious. After the ski cut result, which was significant, we should have put the brakes on immediately and retreated to the safety of the ridge instead of attempting to regroup where I was. This would have prevented my partner being caught. Upon reflection I had not expected anything even close to that size of avalanche and I was embarrassed that we had seriously considered skiing it given our experience. In turn, I believe I downplayed the ski cut result rather than treating that information with the respect it deserved. The signs of instability were obvious, and I should have told my partner to stay put. We were lucky to be given a slap on the wrist in comparison.

We did do a few things right (you would hope so) all of which are a little overshadowed by the mistakes. We had continuous discussion and avidly searched out information. However, the one thing we did really well was ski defensively, ski cutting rather than letting the powder frenzy

take control and centre punching the slope. The ski cut was our last line of defence against our trail of mistakes, and it prevented a potentially much worse outcome. This was not the first time skiing defensively has been beneficial. In patrolling it is a tool of the trade and taught as an essential skill when travelling through terrain. I also train with my transceiver every week and know my own device intimately. When the time comes, regular training is invaluable to a positive outcome.

Statistically speaking, people with only basic levels of education and people who are deemed experts are most likely to be involved in a serious incident. One group knows just enough to get themselves into trouble and not enough to get out. The second group must exercise extreme caution to not succumb to complacency.

In summary I invite people of all levels reading this story to critique our mistakes and analyse the events described. No matter your level of experience always take the time to reflect on your actions in the backcountry. Accept that you will make mistakes and learn from them and be open to feedback. Take every opportunity this winter to learn and get educated and if nothing else remember that the basics save lives. DO TRANSCIEVER CHECKS! Travel in small groups and move one at a time. Maintain continuous open lines of communication and skiing defensively with ski cuts and slope tests will eventually get you out of trouble whether you realise it or not. As humans we often look for information that supports our desires and subconsciously ignore details that go against. This is called confirmation bias and is a sneaky beast that gets the best of us. Ask yourself if you are ignoring the obvious, be ready to accept that you were wrong and change your plan accordingly. Having plan b and c already established helps this. Lastly, be wary of a Considerable forecast. This is when recreationists and dangerous conditions interact the most. Our objective was likely too ambitious for our forecast, match the objective to the conditions.

Backcountry skiing is booming worldwide with a widespread market of quality equipment and a massive social media presence. As a result, we are increasingly seeing people with “all the gear and no idea.” Too often I have seen people pull out probes with price tags still attached and transceivers with no batteries. I implore anyone wanting to take up recreation in avalanche terrain to seek education and mentorship. In doing so you can discover a wonderful world and take pleasure in being able to move through the mountains safely.

Should We Judge Danger or Safety in Avalanche Terrain?

Matthew B Stephensen, Markus Landrø, Jordy Hendrikx

This article first appeared in Volume 126 of the Canadian Avalanche Journal.

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.

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

Kelsey 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 touring in 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, might 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


35°
HOW SAFE ARE THE CONDITIONS?
WHAT EVIDENCE OF SAFETY DO I SEE?
THERE IS NO DEFINITIVE EVIDENCE OF SAFETY, SO I DO NOT BELIEVE THAT IT IS SAFE.
I DO NOT BELIEVE THAT IT IS SAFE, SO I WOULD NOT SKI IT.
HOW DANGEROUS ARE THE CONDITIONS?
WHAT EVIDENCE OF DANGER DO I SEE?
THERE IS NO DEFINITIVE EVIDENCE OF DANGER, SO I DO NOT BELIEVE THAT IT IS DANGEROUS.
I DO NOT BELIEVE THAT IT IS DANGEROUS, SO I WOULD SKI IT.
3

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.

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.

By asking backcountry travelers 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 that 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 how the way you frame the question could influence your users' decisions and think about how you might be able to harness framing to provide that extra margin of safety in times of uncertainty.

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

AVALANCHE SAFETY COURSES 2021

BACKCOUNTRY AVALANCHE COURSES (4-5 DAYS) ARE IN BLACK

AVALANCHE AWARENESS COURSES (2-3 DAYS) ARE IN RED

JUNE

1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26 OENZ	27 OENZ	28
29	30					

JULY

1	2	3	4	5	6	7
8 ASPIRING GUIDES	9 ASPIRING GUIDES	10 ASPIRING GUIDES	11 ASPIRING GUIDES	12	13	14
15	16 NZAC AUCKLAND	17 NZAC AUCKLAND	18 NZAC AUCKLAND	19	20 ASPIRING GUIDES	21 ASPIRING GUIDES
22 ASPIRING GUIDES	23 ALPINE ADVENTURES NZSSI ASPIRING GUIDES	24 ALPINE ADVENTURES NZSSI ASPIRING GUIDES	25 ASPIRING GUIDES	26 NZSSI	27 NZSSI	28 NZSSI
29 BROKEN RIVER NZSSI	30 BROKEN RIVER NZSSI	31 BROKEN RIVER ASPIRING NZSSI ASPIRING				

FOR MORE INFORMATION OR TO BOOK A COURSE GO TO

WWW.AVALANCHE.NET.NZ/EDUCATION/COURSE-PROVIDERS

AUGUST

1 ASPIRING NZSSI ASPIRING	2 ASPIRING GUIDES	3 ASPIRING GUIDES	4 ASPIRING GUIDES	5 ASPIRING GUIDES	6 ALPINE ADVENTURES	7 ALPINE ADVENTURES CHILL
8 CHILL	9 ALPINE GUIDES	10 ALPINE GUIDES	11	12	13	14 OENZ
15 OENZ	16	17	18 OENZ	19 OENZ	20 ALPINE ADVENTURES	21 ALPINE ADVENTURES
22	23	24	25	26	27	28
29	30 OENZ	31 OENZ ALPINE RECREATION				

SEPTEMBER

1 ALPINE RECREATION	2 ALPINE RECREATION BROKEN RIVER	3 ALPINE ADVENTURES ALPINE RECREATION BROKEN RIVER	4 ALPINE ADVENTURES ALPINE RECREATION BROKEN RIVER	5 BROKEN RIVER	6 ALPINE GUIDES BROKEN RIVER	7 ALPINE GUIDES BROKEN RIVER
8 BROKEN RIVER	9 BROKEN RIVER	10 BROKEN RIVER	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31	OCTOBER 8-10 NZAC AUCKLAND			

Scott Walker

NZAA Forecaster Craigieburn Range

Interview by Tom Harris, MSC Partnerships Advisor-Alpine

How did you get into avalanche forecasting? What's your avalanche/snow safety background?

I first learnt to ski in 1993 at the age of 22. I was a prolific mountain biker and rock climber and skiing seemed to be the ultimate way to get into the mountains and learn about this 'snow thing'. I quickly realised how expensive skiing was so I decided the best way to get good at skiing was to work in the industry. Having an earthmoving family, I thought I could be a groomer and work all night and ski all day but the other option was Ski Patrol, where I could, not only ski all day but learn some practical skills to help me in the mountains. I sat Avy 1 (ARM Level 5) in 1995 while working in ski hire at Cardrona and annoying the Ski Patrollers there for the season until I secured a Patrol job at Mt Dobson in 1996. The following year I started at Porter Heights (Porters) and spent 3 seasons in a high Avalanche Zone and learnt from some great, very experienced peers. Porters set me up well for a few seasons ski-bumming in Canada, then on returning home in 2001, I ended up working as a ski guide for Mt Hutt Helicopters. During the season, I had an opportunity to guide at Southern Lakes Heliski, so returned to Queenstown for the next 15 winters. In 2006, I became an assistant ski guide with the NZMGA completing the pathway to full winter guide in 2014. Guiding in the winter has seen me do 3 seasons in Hokkaido, Japan where in 2018 I was the Snow Safety Officer for Rising Sun Guides.

What other work are you involved in within your region for the season besides forecasting?

Winters in Canterbury now see me in a variety of roles. I do a lot of Avalanche Education for Anna Keeling Guiding (AKG) and Broken River Ski Club as well as Guiding for AKG, Alpine Guides and Methven Heliski. I do like to get out touring as much as I can, so always spend time with the patrollers on the range and talking to others in the hills.

Best/favourite aspects of winter/spring recreation in the Craigieburns?

The best aspects of the Craigieburns in the winter is the variety of skiing that the range provides, and the types of people they attract. I love the fact that skiing is pretty low key here, nobody cares what skis you ride or how steep you go and everyone is just out to have fun in the range...

Most overlooked avalanche safety points in your region or in general that you typically see/hear about?

LOW does not mean NO. Each time I drop to LOW hazard I notice some pretty bold lines get skied and ridden. The other point most overlooked in the Craigieburns is the way some people put in their up-tracks. If you are avalanched whilst in uphill mode your chances of skiing out of it are almost Nil! Put your up-tracks in safe areas. Always be thinking "what if?"

What are the unique challenges for forecasting in the Craigieburns?

Forecasting for the Craigieburns is difficult because the snowfall varies so much from North to South and its proximity to the Divide… I have to average out all the data and put in the hazard for the majority of the patch but often, in the far reaches of the patch, where there is less or no data, things could be quite different…

If there was one takeaway point for winter/spring backcountry users in the Craigieburns, what would it be?

Always be thinking "What If…?" 'What if' I missed some crucial data and this avalanches? 'What if' this slope releases while my friends and I are skinning up? 'What if' I drop in on those people and I pull out an avalanche on top of them? 'What if' I sneak under this closure rope and ski in there and I get caught and buried, will someone come looking for me? 'What if' I am buried in an avalanche, will my touring partners be able to dig me out and facilitate a companion rescue? Always run through a worst case scenario and make sure you are prepared for 'What if?'

Any personal winter objectives in 2021?

This season I am keen to double my days touring and also to initiate a 'State of the Snowpack' video blog. Each week I intend to post a short clip of snowpack and skiing conditions for the week and what might be in the forecast for the next week. My other personal goal is to do more Telemark turns. Bad Alpine skiing habits are creeping into my being so they need exorcising…

KEVIN BOEKHOLT

AN NZAD INTERVIEW

Working in Kulusuk East Greenland

Our first interview of the season is with Kevin Boekholt of Alpine Guides. Kevin is a legend amongst the ski guiding community of New Zealand and has a long and storied history of ski guiding around the world. The recent Covid-19 Pandemic has forced Kevin to stay a little more local lately, which means less skiing for him, but also more time doing the other things he enjoys. It also gave us a chance to catch up with the globe trotting skier...

Where were you born and where did you grow up?
I was born in Silverstream near Upper Hutt in the lower North Island

When and where did you start skiing?
I started skiing at Whakapapa when I was 16

What was your first skiing related employment?
I worked as a ski instructor during August holidays at Temple Basin while studying at Lincoln University. I started ski guiding for Alpine Guides at Mt Cook in 1983.

Where do you work now?
I am an owner of Alpine Guides Aoraki Ltd. and mostly guide at Methven Heliski. I also own an international company (Shinsetsu International Ltd.) which predominantly operates ski touring and heliskiing on the East Coast of Greenland and I have some work in Japan. For the past 31 years I have worked as a lead guide for CMH heli skiing in Canada mostly out of Revelstoke but during that time I have worked all over the Columbia Mountains.

What or who influenced you to start skiing (or winter sports in general)?
I was initially a climber but quickly learnt that ski's were the only way to get around during winter and spring. My early guiding was mostly mountaineering and during my assistant guide years I travelled extensively, mostly rock climbing but some expeditions as well. Once qualified I worked in Alaska and Canada and was about to embark on more Himalayan expeditions when I met Hans Gmoser the founder of CMH heli skiing the first heliski company ever and now the largest in the world. Hans offered me a very good contract out of NZK with language training in Japan included. I knew that Canada had the leading avalanche programs in the world and I wanted to move in this direction as I could see things were just developing in NZ and that this was a good opportunity.

Getting deep in the Monashee Mountains at CMH Revelstoke BC Canada.

How did you get started with working as a guide?
I was working for the Park Service as a mountaineer and Alpine Guides would often call looking for someone. I enjoyed working at the Park Service (now DOC) but after my first day heliskiing I knew that being out in the mountains on a sunny August day skiing powder was ultimately what I wanted to be doing.

Who were your mentors or inspiration in your career?
I have been fortunate to have a lot of good mentors. Initially the late Dave Mc Nulty who was the chief guide at Alpine Guides when I started and Hans Gmoser from CMH heli skiing but there were also a lot of CMH guides who helped me in the early years to get established in Canada.

What year did you first go to Canada?
I first guided in Canada in 1987.

What is the biggest change in NZ skiing since you started?
Where do I start with this question given I was working in 1983 before snowboarding, fat ski's, cell phones or the internet! What we ski and how we ski it and the equipment we use has evolved massively in that time. Our understanding of the avalanche phenomena and our corresponding safety programs has improved incrementally. NZ skiing still suffers from good and bad snow years but the high alpine terrain still delivers every season. Obviously the big one is our glaciers are shrinking!

Where is your favourite place to ski?
I don't really have a favourite place although I do like the steep tree skiing in the Monashee Mountains north of Revelstoke. I like Rengee Onsen in Japan, Kamchatka in Russia and north of Kulusuk in East Greenland. NZ has some pretty special places as well.

What's one place (or places) you still want to ski but haven't yet?
I had a guiding trip to Rishiri Island North of Hokkaido this spring that has been postponed to next year. I am keen to do trips in Usbekistan and central Asia.

What event in your career has had the biggest influence or impact on you?
When I first went to Canada I was a qualified IFMGA guide however my snow safety skills were well behind the Canadians at the time. At an early staff training I had to put my ego aside and ask for help and once I had done this I could then start to progress in the right direction. I think stepping away from being a hard core climbing guide into the world of snow science had the biggest impact on my career and the direction it's taken.

What would you tell someone starting out in the snow/avalanche world today?
There is now so much literature, published research and even YouTube videos available that anyone can become immersed


Size 3.5 avalache at CMH Revelstoke BC Canada

in the snow avalanche world. It is easy to gain knowledge but hard to gain experience! Experience is gained over time often by having close calls or near incidents which is not ideal but reality. Gain as much knowledge as you can but realise you will never have enough experience to be an expert in this industry. Basically there are no experts, just people with more experience and knowledge than others so always maintain a cautious approach and always look for opportunities to learn more.

What would you tell 20 year old Kevin Boekholt today?
Don't underestimate uncertainty! An old guide at CMH told me in my early years that "there is always a pocket of instability out there somewhere, the trick is not to have your name on it". Basically, no matter how much knowledge you have of the snowpack there is always an element of uncertainty when dealing with large areas of terrain. As a guide you have to consider all terrain options and to not underestimate the spatial variability of the snowpack.

What gives you the most satisfaction in your work?
I enjoy complex days when there's lots going on. Your mind is racing and you are having to multitask and yet keep a focus on guiding and interacting with your group despite all that's happening around you! Are there techniques, or technology that you use to assist you during complex/busy days? The big thing is to be able to filter the right information. We suffer from information overload these days and it is too easy to keep looking at the computer when the answers are outside!

If you couldn't work as a ski guide anymore, what would you do?
I like rock climbing, mountain biking, photography and travelling in general. I also like business and would probably end up in a different management role.

Can you explain what motivated you to start the businesses you have?
Alpine Guides has been around for a long time and I have just accumulated more shares in it over the years. I set up Shinsetsu International Ltd as my overseas business became more complex and I needed an entity to support everything. Deloitte has been very good at

Snow profile Monashee Mountains BC Canada

Skiing in the Arrowsmith Range, NZ.

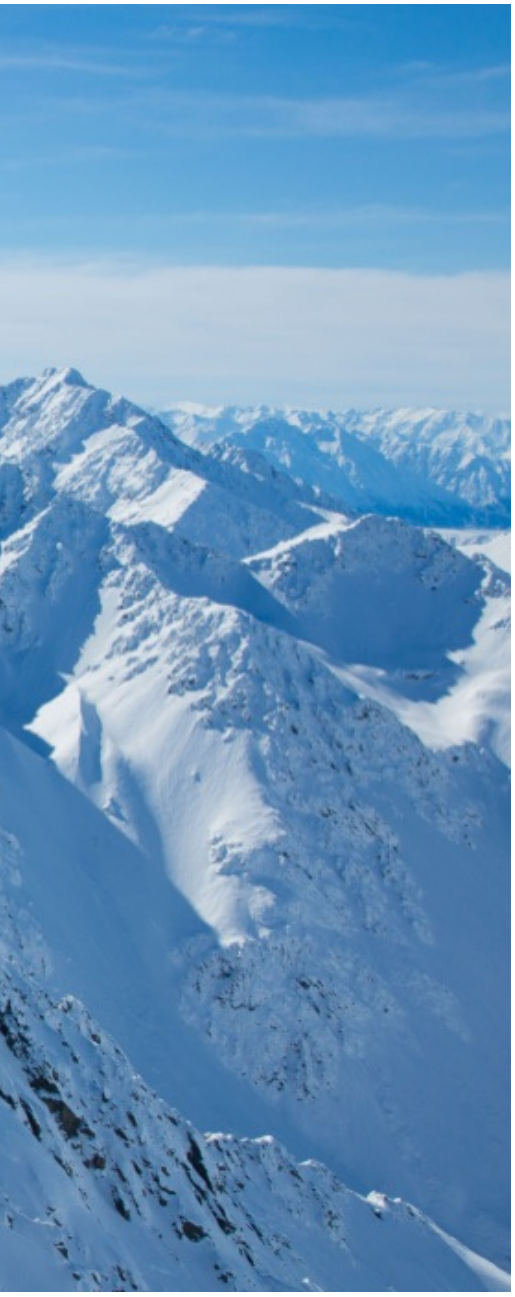
helping me structure business, but the real mentors have been my clients. As a guide you get to spend time with some very successful people, and I have always taken an interest in what my guests do, and these relationships have helped me in my career.

What brings you the most happiness in life?
My family and my work.

What has been your favorite make and model of skis?
I pretty much ski on what I am given and that has been Atomic skis. The "Automatic" 109 (mounted 2cm forward) was a fantastic ski and I now have the "Backland"107 (center mounted) which is also an amazing ski.

What is a piece of skiing or safety equipment that you cannot live without?
The new "Barryvox S transceiver" is pretty nice to use and compact.

Technology and innovation have opened up the backcountry and even heli skiing and inbounds terrain to more people than ever before. Do you see any trends in backcountry or guiding equipment? i.e. do you see too much or not enough reliance on tech?
I had a guide I was training in Canada who had all the run photos, pickup elevations and GPS coordinates on his I phone. He missed the pickup 3 times that day and my advice was leave your phone at home and look out the helicopter window!



What is the biggest challenge facing the NZ skiing industry currently?

Where do I start?... but it has to be excessive compliance costs and then we could move to DOC fees. Basically it is a short season in NZ and many operators struggle to be able to secure qualified staff and can't pay similar wages to overseas companies.

Due in part to Covid travel restrictions many ski fields and other ops are struggling to find qualified ARM 6 staff again this season. Has this affected the heli-ski industry in NZ?

The heliski industry in NZ has a good core of well qualified staff and no shortage of people training through the NZMGA to become ski guides.

How do you prepare for the start of a winter season?

Typically I ski year round so never spend much time off ski's but this year with COVID I will go a full 6 months without skiing. I mountain bike a lot, spend plenty of time climbing and go hunting occasionally. I try and keep active every day!

Because you may be changing from several different snowpacks during any given season, what do you do before you go into a new season or new snowpack? What do you do to start forming a picture of the snowpack?

To start with your mind set is "initial assessment" which means you are in the process of gathering as much information as you can. Before I go into the mountains, I have an idea of what I am looking for in the snowpack regardless of where I am in the world. I build the snowpack in my head from looking at the past weather events and information obtained through other guides. The key is not to go out to look in the snowpack but to go out and investigate what you think may be in the snowpack.

Guides training Methven Heliski Arrowsmith Range

Heliskiing at CMH Revelstoke BC Canada

You also forecast for the MSC NZAA. Can you briefly explain the history of AGL's involvement with the MSC forecast?

Alpine Guides has had an involvement with MSC and the NZAA since it started avalanche forecasting. We cover four forecasting regions throughout the winter including the Mount Cook region which runs year-round. We run the forecasting with a team approach and are in a good position to do this as we have guides working in the mountains year round who are able to feed regular snowpack and avalanche data back to the forecaster.

Have you noticed any particular trends in the NZ snowpack over your career?

You will always have a rain crust in your snowpack and if this happens early season typically it will either facet within the crust or you will end up with faceted snow above it. This will result in a persistent weak layer (PWL) that will last until you get the big rain event in August or early September!

I think that sums up most NZ snowpacks I have dealt with actually! Have there been any particular PWL's during a given season that stand out to you? Explain?

I have been dealing with PWL's for a long time now and it is not the actual layer that stands out but how you managed it (or mismanaged it). I can remember seasons where we could only ski a small selection of runs for weeks on end while we managed a problem.

Have there been any "surprises" or" learning moments" that stand out in your career?

There's been plenty of "surprises" during my career so rather than focus on a specific incident I want to narrow this down to something I think is unique to NZ. Typically we get a lot of wind and relatively dense snow which can result in hard slab formation on steep faces. These slabs often overlay hard ice crusts with some form of faceting either above, below or within the crust. These hard slabs can persist on steep terrain and because they are generally unreactive the hardness factor leads to confidence in their overall stability. Most of my surprises in NZ have been as a result of underestimating the potential for hard slab avalanches to persist on steep terrain during periods of moderate hazard.

When I first started guiding an instruction group triggered a deep slab avalanche in Beetham Stream (Aoraki region) while learning to crampon. A few years later I was guiding by the old pioneer hut site under Alack Peak. We were cramponing in firm conditions when there was a loud cracking noise and the slope below us released to size 2.5 with big blocks. The crown wall was 1.5 meters deep and the bed surface was a hard ice crust. The layering was mostly pencil hardness and we got no results from strength tests before so in effect we just had a very big piece of snow under tension that decided to release!

Have you noticed any particular trends in the NZ snow climate over your career?
Every season is different but it is definitely getting warmer and there is a lot less ice and some big lakes at the bottom of heliski runs.

Have you had to adjust your approach (personally or business-wise) to this trend? i.e. do some runs just not get skied anymore? harder to find good snow? etc.
Both Methven and Mt Cook Heliski have plenty of high elevation terrain that tends to get snow from most storms so if anything, it is just the length of runs that varies between good and bad seasons.

Can you describe your most difficult day of guiding work?
I was lead guiding during a very unstable period in Canada and was on my last day of a 21 day work stretch. We were just touching down in the helicopter when we got called to Rogers pass to an avalanche accident where there were 7 fatalities. It's a long story but after everyone was dug out we used our helicopter to load the bodies out just on dark as it was starting to snow. We only just got out!

Was this the infamous and tragic Connaught Creek accident that killed seven teenaged school kids? Or the Durrand Glacier accident that same year? Or a different one than those?
I actually responded to both these accidents, it was a bad run. I have worked the past 30 seasons from Revelstoke BC which is central to Cat, Heli, snowmobile and recreational terrain so we do get asked to respond at times.

Natural release with cooling temps at CMH Revelstoke BC

What (if any) "Golden Rule" (or rules) guide you in your work?
Running helicopter ski programs is not an easy job and it takes many years of experience to even start to become comfortable in a lead position. There are no golden rules as such! To start with you need to be totally comfortable with your own level of competence in the mountains so that the skills associated with the guiding component come naturally. The snowpack assessment and decision making is a Bayesian process where you are adding incremental information as you go along! This is ongoing and you live the snowpack through the season! Daily operations start with rule based decision making and incorporate a team approach. Ultimately when you are lead guiding after a storm you have to be totally immersed in the decision making process and draw on all the experience you have managed to accumulate to make a decision on where to land. Just because you have landed doesn't mean you have to ski the run and at this point it is time to reassess your decision and to take time to dig or look around for further information. When you feel totally comfortable still wait for the next load to be close by so you have a backup and then proceed. If you don't feel comfortable change your plan and fly somewhere else.

Gaining backcountry experience (and confidence) is a bit of a Catch-22: How do people gain more backcountry experience, but also stay as safe as possible? What would you tell someone who wants to get more backcountry experience? There are plenty of good opportunities to learn these days and the number of people taking backcountry avalanches courses is at an all time high. My advice is to do a course or any backcountry trip with a qualified guide and you will be impressed by how much information you can simply absorb by being in the right environment.

Skiing in the Selkirk Mountains BC Canada

Skiing to the ocean Kulusk East Greenland

Can you describe a "favourite day" of guiding work?
My favourite days of guiding are heliskiing when you don't get stuck in a particular zone but keep travelling through the mountains managing risk, efficiency, fuel and produce a fantastic tour that changes with every run!

Do you have "difficult clients" and/or how do you deal with client expectations and reality?
No we don't have difficult clients, the job is to give everyone an amazing day out in the mountains which should not be that hard given the environment we work in. If we have stability issues and can't ski big lines then we tell the guests and this helps to set the expectations before the day; everyone still comes!

How has the Covid 19 pandemic affected your work?
We actually had a very busy winter in 2020 at Alpine Guides with some good snow conditions. Typically I would have gone overseas but this summer I have been at Mt Cook which has been lots of fun. I started working on the SAR team in 1989 at Mt Cook so living in the village and putting energy into Alpine Guides has been great for me. My overseas business has suffered but my rockclimbing has improved!

Any preparations for the "post-Covid pandemic world" from your businesses standpoint? Or wait and see?
Last season we had great support from kiwi guests and I think people were surprised by how good it actually is to be tourists in NZ. We have a very loyal Aussie cliental so they will be back as soon as they get the chance.

LAKE ERSKINE

44 50' 26" S 167 59' 33" E ELEVATION: 1322 M

PHOTO COURTESY OF MILFORD ROAD ALLIANCE

IN 2019 WE CAPTURED THIS STUNNING PHOTO SHOWING THE OUTCOME OF A LARGE AVALANCHE THAT HAD IMPACTED LAKE ERSKINE DURING A RECENT STORM.

FROM THE BUCKLED ICE REMAINS ON THE NEAR SHORE OF THE LAKE YOU CAN SEE THE INITIAL IMPACT OF THE AVALANCHE AND THE SHATTERING, SPIDER WEB EFFECT ON THE ICE. A WAVE WAS THEN GENERATED, THAT PROPAGATED OUTWARD FROM THE IMPACT ZONE. AS THE WAVE TRAVELLED ACROSS THE LAKE, IT WAS REFLECTED FROM THE OPPOSITE SHORELINE; YOU CAN SEE A DIFFERENT PATTERN OF ICE CRACKING THERE.

A LARGE NUMBER OF STUDIES ON THE IMPACT OF LANDSLIDES INTO BODIES OF WATER EXIST, BUT IT IS RARE TO DOCUMENT THIS TYPE OF AVALANCHE IMPACTING A BODY OF WATER .

- SIMON MORRIS

KNOW YOUR SNOW

NIWA Environmental Technician Hamish Sutton doing maintenance work on the Upper Rakaia Snow and Ice station.
Image: Alec Dempster, NIWA.

With the winter snowpack starting to build who's keeping an eye out for conditions in the mountains? Sam Fraser-Baxter looks at a remote network of weather stations helping keep alpine adventurers safe.

It's a mountaineers' worst nightmare -

a loud crack, then a cascade of snow and ice hurtling downhill.

Avalanches have claimed the lives of 27 people in New Zealand in the past two decades.

Knowing exactly when and where an avalanche might occur is a bit like trying to predict lightning.

But with NIWA's help, the Mountain Safety Council (MSC) can effectively forecast the degree of avalanche danger for those venturing into the backcountry mountains.

lakes and large areas of the South Island rely on meltwater for irrigation. Snowflakes themselves are big business - in 2019 alone, there were about 1.7 million visitors to ski fields in New Zealand.

"Understanding the amount, seasonal nature and long-term changes to snow and ice is hugely important – especially with a warming climate," says Zammit.

But at the time, there was no infrastructure to help measure how much water was stored as snow in our mountains.

Snowflakes themselves are big business - in 2019 alone, there were about 1.7 million visitors to ski fields in New Zealand.

It's one of just a range of services flowing from the data gathered by a network of 11 high elevation weather stations set up and maintained by NIWA's environmental technicians.

Hydrologist Dr Christian Zammit is the current custodian of NIWA's alpine weather network.

The genesis of the network can be traced back to the mid-2000s. At the time, growing awareness of climate change was starting to prompt questions about New Zealand's future water supply.

Snow plays a significant role in both our national water flows and the economy. Snow melt contributes to as much as 30% of the intake of major hydro-electricity

NIWA's solution was hugely ambitious – a network of alpine weather stations that would record the depth, density and temperature of snow, as well as a range of other climate measurements such as precipitation, wind speed, temperature and humidity.

In 2008, after years of intensive planning, NIWA technicians headed into the mountains to start installing the equipment needed to gather that data.

It was no easy network to set up. Situated in some of New Zealand's harshest environments, the stations had to endure freezing temperatures, gale force winds, lightning, heavy rain and, of course, heavy snow.

They also needed to deal with kea – the mountain parrot notorious for pecking and ripping apart anything they get their beaks on.

NIWA's environmental monitoring technicians learnt many lessons the hard way. The wind sensors, for example, require special modifications to thwart the inqu isitive birds.

Five years later, however, the snow and ice monitoring network was complete, made up of 10 high elevation stations running the length of the Southern Alps and one on Mount Ruapehu.

With specialist recording instruments in place from Fiordland to Tongariro National Park, the network covers a representative range of distinct high-altitude areas between 800 and 2200 metres above sea-level.

The stations, and the long-term data series they provide, play a pivotal role in delivering insights into the ever-changing alpine climate to everyone from power planners and hydrologists, to farmers and ski field operators.

It is also crucial in helping the Mountain Safety Council (MSC) shape its avalanche forecasts for recreational backcountry users such as mountaineers, ski tourers, winter trampers or anyone else venturing into vulnerable areas.

Unlike ski fields, backcountry mountains are neither patrolled nor controlled, so understanding the condition of the snowpack and the avalanche threat it poses is vital.

The MSC's forecasts are compiled by experienced snow safety professionals with an expert knowledge of avalanche phenomena. They use data from the NIWA network, coupled with direct observations from the field.

"Over the course of days, weeks and months, forecasters can start to build an understanding of what the snowpack is doing and how it is changing. Continuous flow of data from these stations is really important," says MSC operations manager Nathan Watson.

Avalanche forecasts covering 12 alpine regions, are published daily during the snow season on the MSC's Avalanche Advisory website (www.avalanche.net.nz).

They provide a rating for the avalanche danger - low, moderate, considerable, high, and extreme – across three elevation bands: sub alpine, alpine and high alpine.

"In a storm cycle, usually no one is in the field observing the snow – there's no one out heli-skiing, climbing or touring. So, you're relying on the stations and the weather data to paint a picture of what's going on."

The value of those stations, and the information they supply, will only go up as our climate warms.

Zammit says while researchers expect higher snowlines and less snow in future years, that will not necessarily mean less avalanche danger.

There might be less snow days, says Zammit, but expect larger amounts of snow falling during storm events.

"With climate change, the extremes get more extreme."

Even more reason to ensure the data keeps flowing off the mountains.

Listening to

Debris from an explosives triggered, size 4 avalanche from September 2020 along State Highway 94.
Photo courtesy of Milford Road Alliance.

Avalanches

By Leighton Watson

The snow avalanches that occur along the Milford Road threaten people and infrastructure and are some of the most spectacular avalanches in the world. The Milford Road Alliance (MRA) uses snowpack data, visual observations, and high-resolution weather forecasts to assess the avalanche hazard and monitor avalanche activity. In recent years infrasound, which refers to the low frequency sound waves in the atmosphere that an avalanche generates as it moves downslope and pushes the air out of the way, has emerged as a promising monitoring tool.

Low frequency sound waves in the atmosphere are generated by a range of natural (volcanic eruptions, earthquakes, tsunamis, meteors) and man-made (explosions, jet engines, nuclear bombs) sources. These low frequency sound waves are referred to as infrasound because they are at frequencies below the lower limit of human hearing, which is defined as 20 Hz. This is the opposite to ultrasound, which is above the upper limit of human hearing (> 20,000 Hz) and is the frequency range that bats use for echolocation. Some large animals such as whales and elephants can use infrasound signals to communicate.

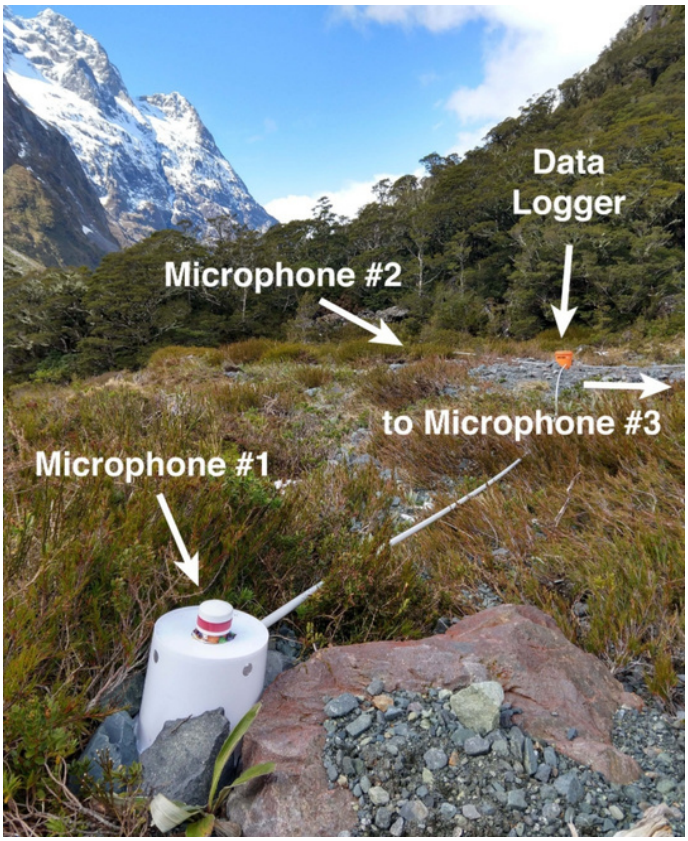


Fig 1. Photograph of the infrasound array deployed at Crib Wall. Microphone #1 is shown in the foreground with an upside-down 20 L plastic bucket used to protect the microphone from water and kea. The microphone is connected by cables to the data logger, which is in an orange plastic bucket. The location of the other two microphones in the array is indicated. The cables are threaded through flexible plastic tubing to protect from Kea.

Snow avalanches generate infrasound signals because the rapid motion of the avalanche displaces air. This creates a pressure perturbation in the atmosphere that propagates as a sound wave which can be recorded by specialized microphones. Several studies in North America and Europe have

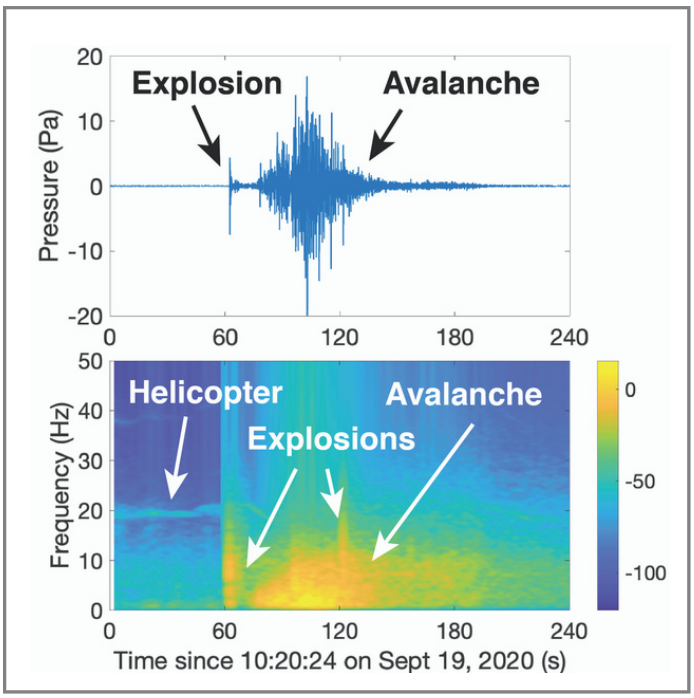


Fig 2. Infrasound signal from a triggered event. (above Infrasound signal in the time domain. The impulsive signal at 60 s is the explosion. (b) Infrasound signal in the frequency domain. The vertical band at 60 s is the explosion and the avalanche signal is the extended signal started at approximately 80 s. The horizontal bands are rotor noise from the helicopter.

shown how infrasound observations can be used to detect, locate, and characterize avalanche activity.

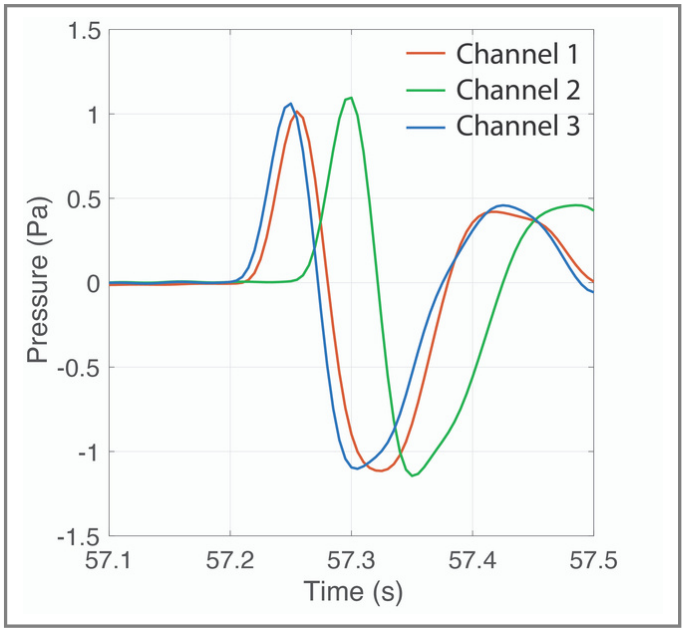
In the winter of 2020, we carried out a pilot study about infrasound monitoring of snow avalanches along the Milford Road. We deployed two infrasound arrays on the eastern side of the Homer Tunnel with one array near Homer Hut and the other array at Crib Wall, which is close to the MRA's Alpine Operation Center. Each array (Fig. 1) consisted of three infrasound sensors (specialized microphones that are sensitive at low frequencies) connected to a data logger. The Fiordland environment is unforgiving and we had to design a novel system to protect the equipment from both the inclement weather and inquisitive keas.

The infrasound equipment was installed the day before an Active Control (AC) campaign, and was able to record explosions, avalanches, and helicopter noise during the AC. During the AC campaign, a size 4 avalanche was triggered from the Raspberry slide path and the infrasound signal is shown in Fig. 2.

The infrasound signals recorded during this field campaign were up to 100 times larger than signals that have been previously recorded at other sites, which illustrates the massive scale of avalanches along the Milford Road. The bottom plot shows the spectrogram, which shows how the frequency components of the signal change with time. Warm colors (e.g., yellows) are high amplitude while the cool colours (e.g., blues) are low amplitude. The vertical bands are broadband signals from the explosions while the horizontal band is due to the rotor noise of the helicopter. The avalanche signal is from 70 s to about 180 s and is concentrated below 20 Hz (hence why it is termed infrasound).

We left the equipment in the field for approximately four weeks after the AC campaign. During this time, we recorded several natural avalanches, some of which occurred during the daytime and were independently observed by avalanche technicians and some that occurred during the nighttime and would otherwise have been undetected.

By using arrays of sensors, we are able to calculate where the sound waves are coming from. An example is shown in Fig. 3 where the sound waves arrive at Channel 3 first, followed quickly by Channel 1, and then Channel 2. Based on this information, we can determine that the sound wave came from the southeast.



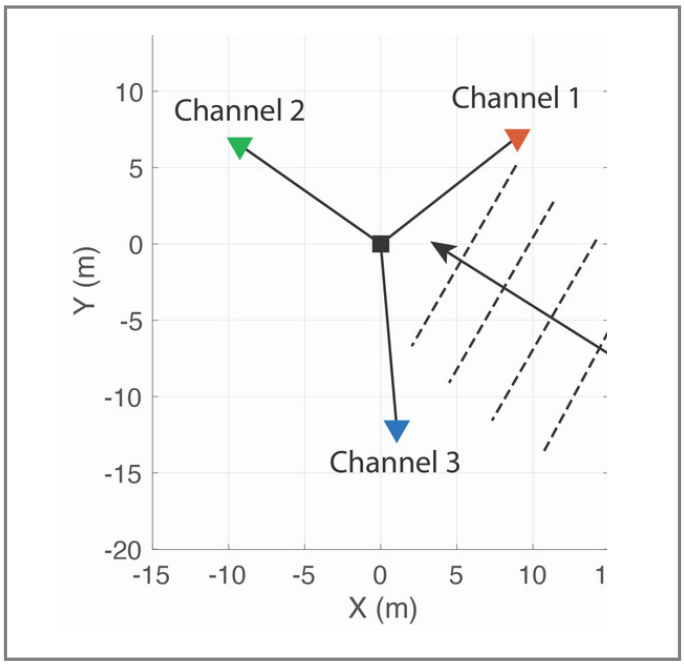


Fig. 3. (top figure): Zoom in on the first arrival of the infrasound signal. The sound wave arrives at Channel 3 (blue) first, followed closely by Channel 1 (red) and then Channel 2 (green). Lower image: Schematic of an infrasound array showing where the sound wave came from.

Because we had two arrays, we are able to calculate the back-azimuth bearing from each array and combine to triangulate the source location. Fig. 4 (next page) shows an example of the source localization for a size 4 triggered avalanche from the Raspberry slide path.

This pilot study shows how infrasound can be used to monitor snow avalanche activity along the Milford Road and in other alpine regions. Infrasound can provide continuous observations of avalanche activity over a large geographic area.

Infrasound observations can provide useful information about avalanche location, size, and type. While infrasound is a useful tool, it will be most beneficial when integrated with other monitoring efforts (visual observations, snowpack data, weather forecasts).

Figure 4 (a-c): AC triggered avalanche (T1) that occurred around 10:22 on Sept 19, 2020. (a) Infrasound time series from MCW Channel 1 (blue) and mean cross-correlation for MCW (black). (b) Infrasound time series from MHH Channel 1 (red) and mean cross-correlation for MHH (black). (c) Back azimuth bearings from MCW (blue) and MHH (red).

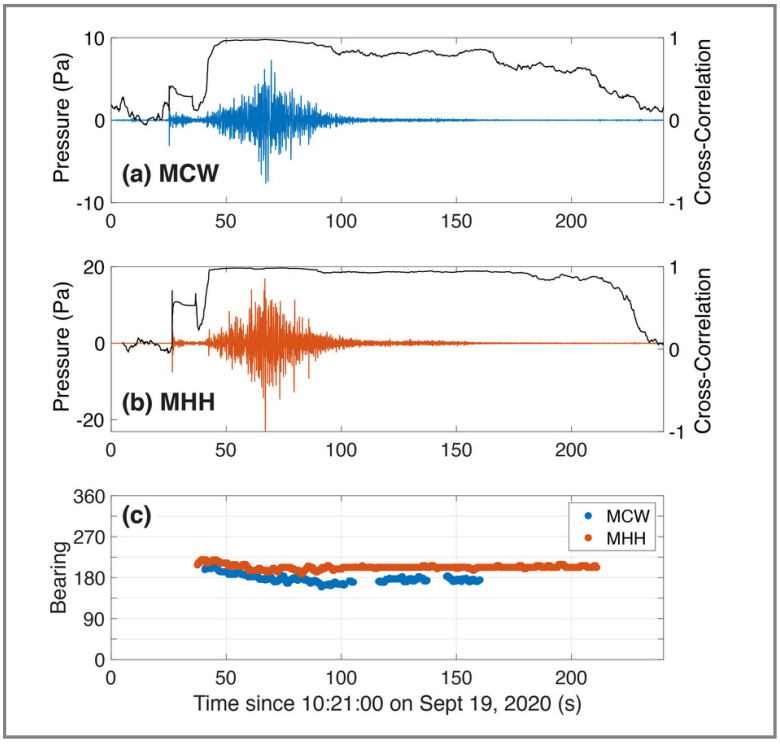
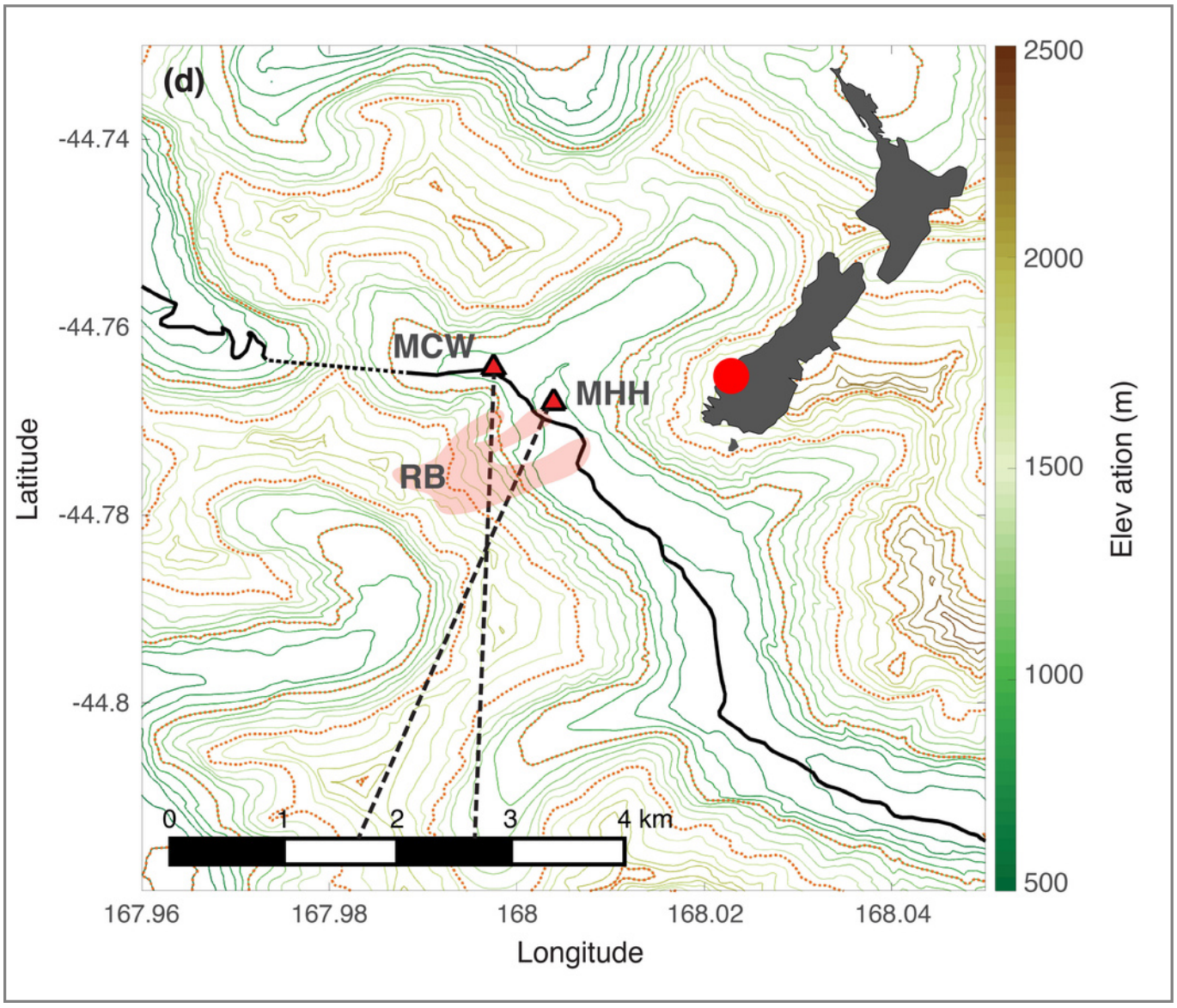


Figure 4 (d): Topographic map (below) showing station location (red triangles), mean back-azimuths (black, dotted), and Raspberry Slide path (red, shaded), where the avalanche occurred. The red circle on the inset map of New Zealand shows the approximate location of our field site along the Milford Road.



Mountain Research Centre Project Updates

Compiled By: Aubrey Miller

Atmospheric rivers and extreme weather events

New research has led to a detailed assessment of the impacts of atmospheric rivers, which are defined as narrow corridors of concentrated moisture in the atmosphere. They hold relevance for those in the ski industry as they can lead to heavy or extreme snowfall events. A detection algorithm has been used to build a climatology of these events over the period 1979-2019 (Prince et al., 2021), which will be an important benchmark for further assessment of how these extreme precipitation events will evolve in the future. Further work using a state-of-the-art regional atmospheric model has also revealed more closely the nature of the orographic processes responsible for precipitation during an atmospheric river event (Kropac et al., 2021). There remains a weakness in the way we can forecast how weather systems will impinge on the Southern Alps, in particular how much snowfall in winter a system will bear. This latest research explores some of this uncertainty and is another stepping stone in developing more robust tools to forecast the impacts of our extreme weather events. The key for the survival of our winter snowpacks in the future might be the reliance on "big storms that bring big snow". You can learn more and view an animation of atmospheric rivers here: https://www.otago.ac.nz/news/news/otago823843.html

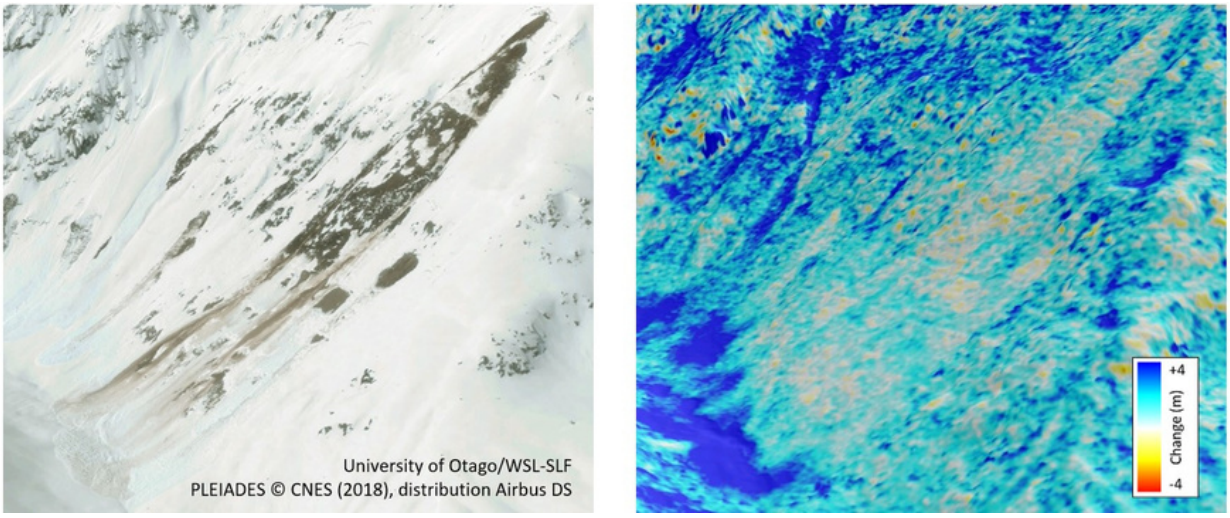


Figure 1: Pleaides 50cm satellite image (left) and corresponding area of 3D change between summer and winter terrain, highlighting a recent wet avalanche immediately before the winter image was captured.

Mapping snow depth from satellite

The Matariki Project (https://www.otago.ac.nz/surveying/potree/matariki/) aims to leverage the increasing capacity of stereo imaging from satellites at very high resolution to capture and measure changes in surface elevation produced by a range of environmental phenomena. In this context, being able to map snow depth in remote mountainous terrain from space is a challenge that will greatly improve our understanding of snow distribution, and thus contribute to avalanche science. In collaboration with colleagues from the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL-SLF), we achieved sub-metre accuracy in mapping snow depth with Pléiades satellites across large mountainous terrain in Davos, Switzerland (Eberhard et al., 2021). This outcome is timely and promising as the first of four next generation Pléiades-Neo satellites was successfully launched in April 2021, and will bring significantly improved resolution (30cm) and imaging availability in the future, including in Aotearoa New Zealand. Figure 1 illustrates the 3D topography change between summer and winter and highlights the erosion and deposition from a recent avalanche in the Dischma Valley, Switzerland.

Avalanche modelling in New Zealand

Milford Road

The work we started last year that draws from recent advances in mapping alpine topography (Matariki project) to support avalanche modelling in New Zealand is progressing well. Since the last NZAD issue we have been focused on calibrating RAMMS simulations in Fiordland, in collaboration with the Milford Road Alliance (MRA) and WSL-SLF in Switzerland. We have calibrated the scientific version of RAMMS for both core-flow and powder-cloud simulations based on a large avalanche in the McPherson path in September 2020. Figures 2a and 2b (right and far right) shows the modelled surface difference (erosion and deposition) from the avalanche event with the release areas and deposition areas noted by the green and orange polygons. The deposition area was delineated based on a Planet Labs (2020) satellite image immediately following the avalanche.

Working with Simon Morris from MRA, we have integrated his very high-resolution LiDAR scans with satellite imagery-derived 3D elevation information, capturing the steep Fiordland terrain in fine detail. The level of detail in the terrain data now held digitally will support more precise RAMMS simulations. Next steps will be further calibration of RAMMS with several other recently documented avalanches along Milford Road before doing scenario simulations (e.g., what snow conditions in release area and track would be necessary for a core hit to the road) in support of MRA planning.

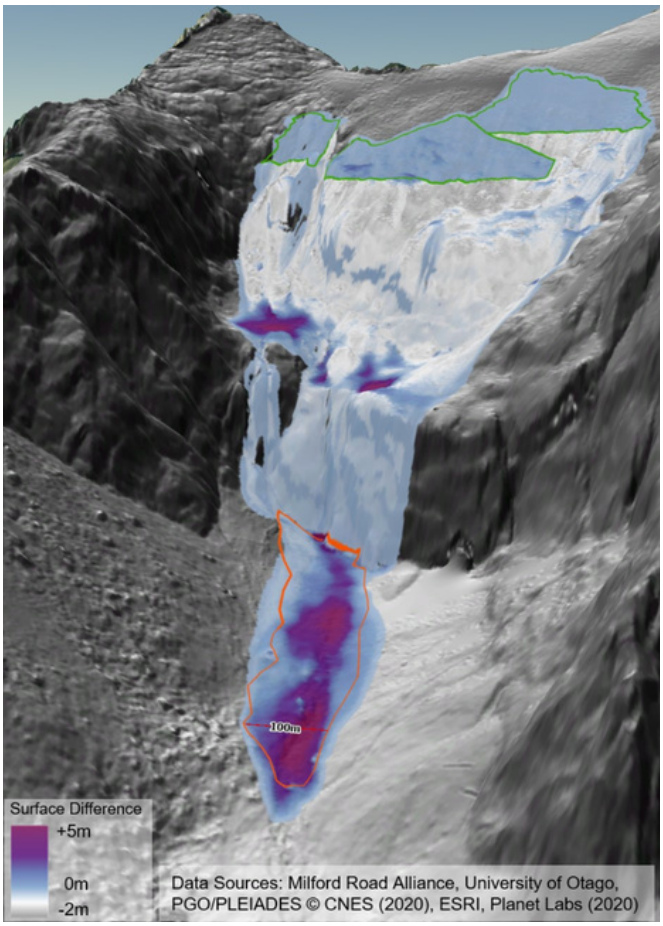


Figure 2a: RAMMS modelling result for McPherson Path September 2020 avalanche near Milford Road, depicting the surface difference (areas of erosion and deposition) and the footprint of the deposition area as seen in a Planet Labs (2020) image the day of the avalanche.

Aoraki Mount Cook National Park

We have also started avalanche research in Aoraki Mount Cook National Park. For her 2020/2021 summer studentship, Anna Smith conducted an exhaustive inventory of avalanche events in the Hooker Valley from the VENµS satellite sensor. She documented and measured all the avalanche debris visible in the imagery archive over several seasons, creating a valuable database of avalanche events and helping assess the frequency and magnitude of avalanches here. These data will be used to better understand patterns in avalanche activity in a drastically evolving alpine landscape. Figure 3 (at right) shows a subset of her inventory of avalanches occurring in the Hooker Valley and visible over the imaging period (November 2017 – July 2020).

To complement the large volume of satellite data available for avalanche research, we are installing time-lapse cameras in the Hooker Valley in collaboration with the Department of Conservation. This will help assess the frequency and magnitude of avalanches on cloudy days and help narrow down the timing of the events. Both datasets will be used to calibrate extreme event RAMMS simulations to support preparedness, especially as the landscape continues to rapidly erode.

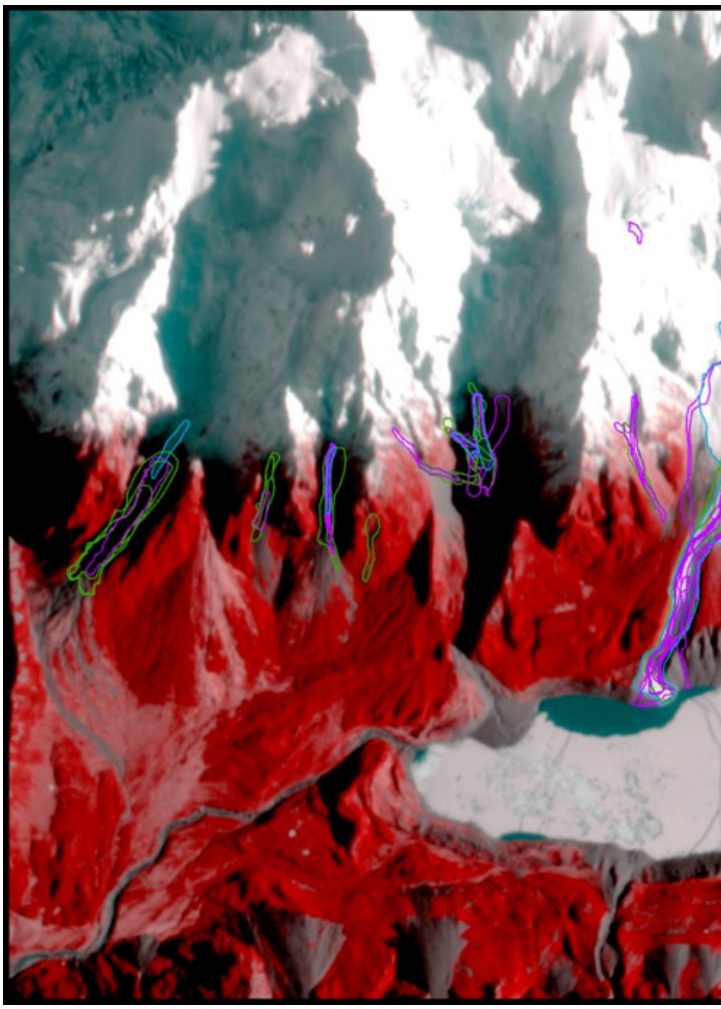


Figure 2b: An explosives triggered, size 4+ deep slab avalanche from Mt McPherson, Fiordland National Park. Photo courtesy of Milford Road Alliance.

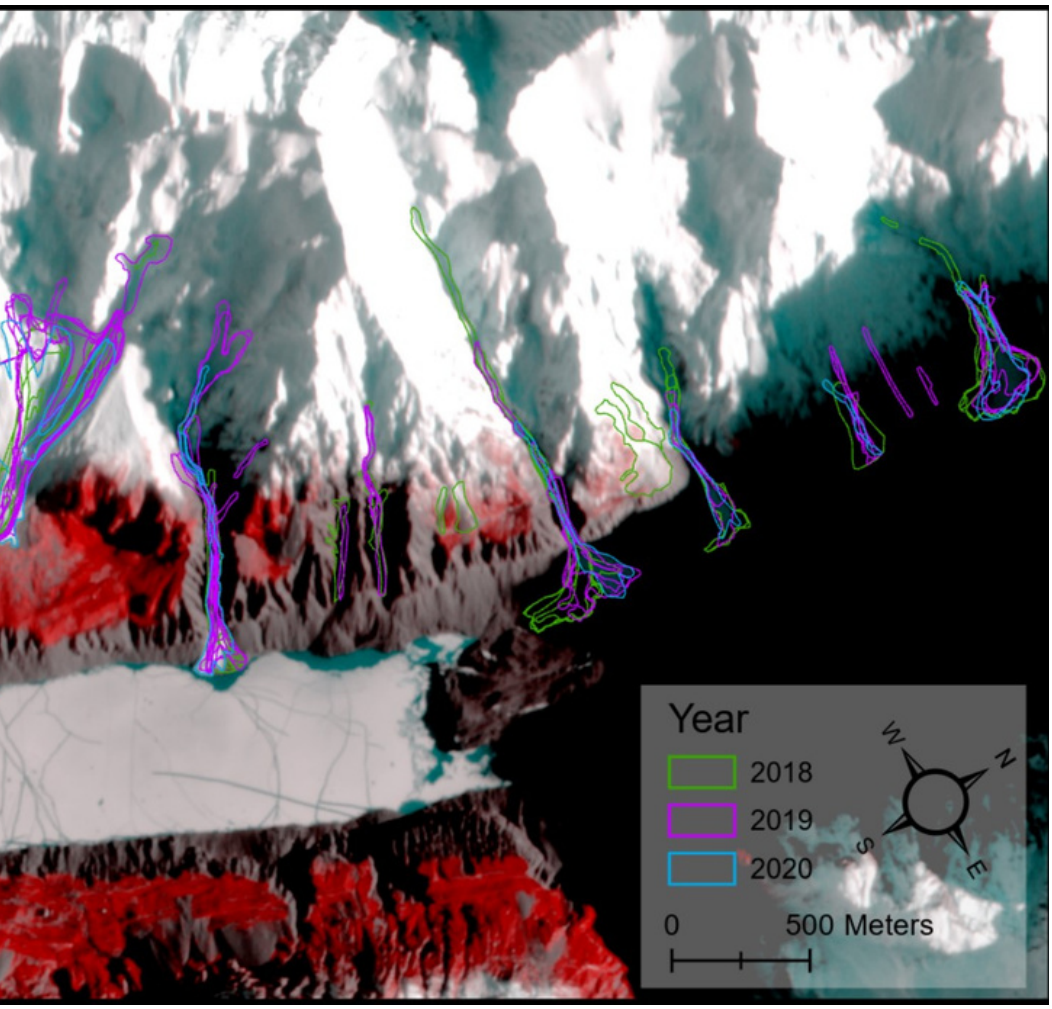


Figure 3: Example of avalanche inventory visible from VENµS satellite imagery over period of Nov 2017-July 2020 in the Hooker Valley, Aoraki Mount Cook National Park. The coloured polygons correspond to the year of the avalanche event and are draped on a false-colour image VENµS image from July 2020.

Seasonal snow monitoring

It won't be news to many readers that winter 2020 was a "fairly lean" snow season through most of the Southern Alps. The MRC processes snow covered area (SCA) from NASA's MODIS satellite sensor to provide information for the South Island in near-real time (Figure 4). Extending back to the year 2000, this record shows clearly that, despite a promising start, a substantial snow cover deficit occurred during winter 2020. This was most apparent through August when SCA was well below average. The full interactive record can be accessed at: https://www.otago.ac.nz/surveying/potree/pub/mrc/projects/snotago/modis-snow-cover

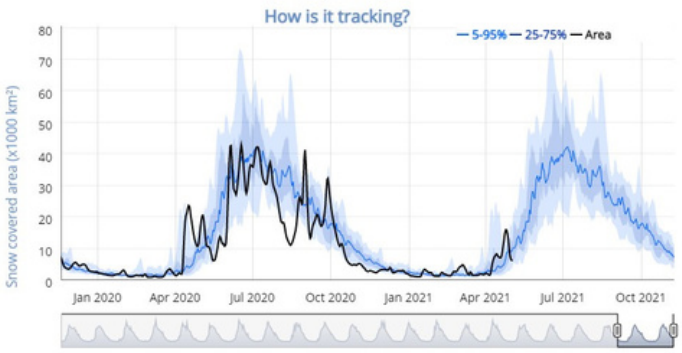


Figure 4: MODIS snow covered area curve for 2020 and 2021, from https://www.otago.ac.nz/surveying/potree/pub/mrc/projects/snotago/modis-snow-cover.

Since winter 2016, MRC members have been maintaining an automatic weather station (AWS) in the Pisa Range. The AWS is located within a small basin that provides a field site for snow hydrology, climatology, and alpine ecology research. Located at 1500 m, this weather station and field site provide us with important meteorological and snowpack observations in an area where processes differ from those occurring on the main divide. Telemetry was installed at the AWS in winter 2020, and real time data can be accessed on the MRC website:
https://www.otago.ac.nz/surveying/potree/pub/mrc/projects/snotago/pisa-snow-site.

Just like the MODIS record, the observations made here to date highlight both the degree of variability within and between snow seasons and the particularly lean nature of winter 2020 (Figure 5). The specific position of the station means that a thin snowpack is quite common. An increase in east to south-east airflow through the winter of 2018 provided a big boost to the Pisa Range snowpack.

As for the coming winter? While we are still some way off being able to reliably predict snow at seasonal

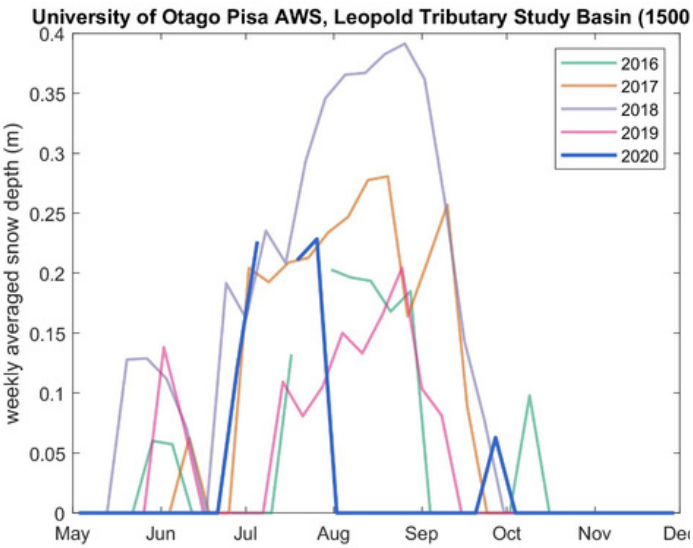


Figure 5: Weekly averaged snow depth for the winters of 2016, 2017, 2018, 2019 and 2020.

timescales in New Zealand, current indications for the medium term suggest that continued warm and settled conditions are likely to persist into early winter. These conditions, driven in large part by the influence of high pressure, are better known for growing facets within an established snowpack in early winter rather than being responsible for the early season build-up of a snowpack. The El Niño Southern Oscillation is currently in neutral territory, so it seems unlikely that we will see either El Niño or La Niña strongly impact our weather this winter. Sea surface temperatures remain above average to the south and east of the South Island. While this can be expected to have a warming influence on air temperatures, there's also the chance of enhanced convection, and increased precipitation, accompanying any southerly outbreaks that reach our shores. As always in New Zealand, the origin, timing, and intensity of specific storms will control snowpack development. Timing is everything, and time will likely tell again how "good" our season will be.

Mountain Research Centre
Aotearoa – New Zealand

Comparing Extended Column Test results to signs of instability in the surrounding slopes

Exploring a large international data set

Frank Techel, Karl Birkeland, Doug Chabot, Jim Earl, Ivan Moner, Ron Simenhois

This article first appeared in The Avalanche Review 39.1

Since its introduction in 2006, the Extended Column Test (ECT) has become one of the most popular tests to assess point snow instability. In 2009, two studies explored how ECT results correlated to observed instabilities, laying the foundation for the tests' interpretation we are using today. Based on data from the first winters, Ron Simenhois and Karl Birkeland showed that ECTVs and ECTPs were typically observed when conditions indicated instability, while ECTNs and ECTXs were mostly observed on stable slopes (for ECT scoring abbreviations refer to observational guidelines [Greene et al., 2010]). This continues to be the standard for interpreting ECTs in the United States. In Switzerland, Kurt Winkler and Jürg Schweizer noted that ECTP≤21 detected a large proportion of unstable slopes correctly while keeping the number of false alarms low. Again, ECTNs or ECTXs were more frequently associated with stable slopes in their study. In Switzerland, this is the operationally used approach to classify ECT results.

Now, more than ten years later, the ECT is a well-established test internationally. The time is right to revisit these stability interpretations, as recently done using Swiss data (Techel et al., 2020), by combining ECTs from North America (mostly from the U.S.), Spain, and Switzerland.

What data did we use?

We explored several snow profile databases from snowpilot.org, Val d'Aran (Spain) and Switzerland. We only included backcountry snowpit profiles with ECT results and information about the presence or absence of clear signs of instability. In total, we had:

- 2,579 ECTs from snowpilot.org, with about 90% from U.S. (snowpilot.org is open to the public)
- 167 ECTs from Val d'Aran / Spain, with profiles mostly collected by forecasters and observers
- 1,226 ECTs from Switzerland, with profiles observed by researchers and field observers

These ECTs are therefore just a small subset of the more than 30,000 combined ECTs in these databases.

How did we analyze the data?

For each ECT, if more than one failure was indicated we used the following rules to decide which result was the most relevant for stability assessment:

1. If an ECTV or ECTP failure was recorded: we considered the lowest number of taps required for full propagation.
2. If full propagation was not observed, we considered the lowest number of taps associated with the ECTN or ECTX.

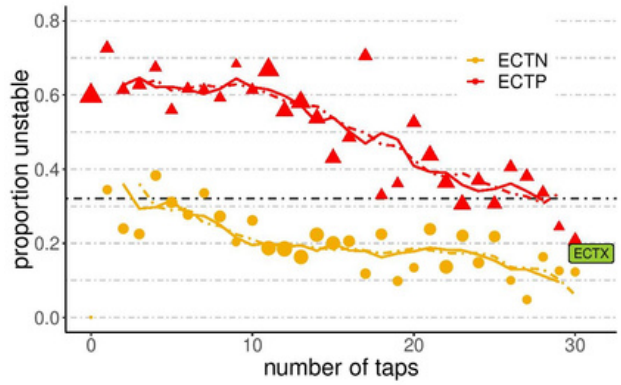


Fig. 1. Proportion of unstable ECT locations for each combination of fracture propagation and number of taps until failure. The larger the symbols, the more data points. The respective colored lines represent a running average, calculated over five consecutive number of taps. The black dashed line represents the base rate, the proportion of unstable locations in the data set. ECTP (red triangles) were observed more often in unstable locations (above the black dashed line), ECTN (yellow circles), and ECTX in stable locations. The proportion of unstable locations for ECTP>22 and ECTN≤8 neither truly indicated unstable or stable conditions.

If there were several ECT results in the same snow pit, we randomly picked one. This provided us with a dataset of almost 4,000 ECT results.

We classified the stability of each ECT location by relying on observed signs of instability in its surroundings.

We considered ECT locations to be unstable when signs of instability (such as cracking or collapsing) or recent avalanches were observed in surrounding slopes. If observers clearly stated that neither signs of instability nor recent avalanches were present, or if they indicated that the slope in question was skied or snowmobiled (in the U.S.), we considered these locations to be stable. In our dataset 32% of the ECT locations were classified as unstable and 68% as stable. These are our base rates, and we will compare the results of the tests to these base rates.

For those of you interested in a little more information on our analyses, read this paragraph. If you are not interested, feel free to skip to the next paragraph:

For a more scientific and detailed description, we refer you to Techel et al. (2020). In short, for each combination of ECT results (whether or not it propagated and the number of taps), we calculated the proportion of tests associated with observations of instability. To smooth the scatter in our results, we calculated a running mean of the proportion of unstable observations for five consecutive numbers of taps. We then asked: Is the proportion of unstable slopes of a specific ECT result (propagation and number of taps) significantly higher (or lower) than our base rate (0.32)? If the proportion unstable was higher than the base rate, the respective ECT result (propagation and number of taps) was clearly observed more often in unstable locations, confirming this result was more commonly associated with unstable conditions. If the proportion unstable was lower than the base rate (0.32) then those results correlated more often with stable conditions. Values that were not significantly different from the base rate were interpreted as neither truly unstable nor stable.

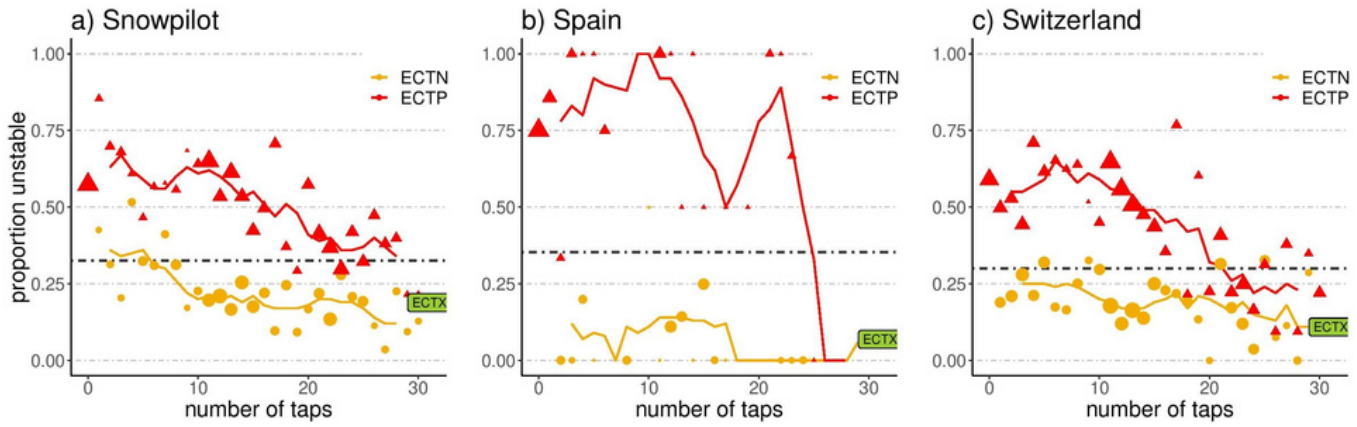


Fig. 2: Proportion of unstable ECT locations for each combination of fracture propagation and number of taps until failure for the three data sets. The Snowpilot (a) and Swiss (c) results, which are based on a large number of ECT, look rather similar. In contrast, the ECT data from Spain discriminates better between ECT results indicating instability and stability, but also a much more random behavior due to the small number of ECTs.

What did we find?

Quite clearly, ECTVs and ECTPs are observed more often on unstable slopes (red line in Fig. 1 located above the base rate, represented by the dashed black line), while ECTNs and ECTXs are observed more commonly on stable slopes (yellow line located below the base rate) (Fig. 1). Further, ECTs with a higher number of taps tend to be more stable. ECTPs with less than 14 taps were the most unstable, with about 60% of those tests being associated with avalanches or signs of instability. This is about double the number of locations associated with avalanches or signs of instability in our entire dataset (the base rate). While still clearly on the unstable side of the base rate, the proportion of unstable locations decreases with more taps, even with an ECTP result. When more than 22 taps are necessary to initiate a fracture in an ECTP, the proportion of unstable slopes was not significantly higher than the base rate, indicating that such results might be linked to something like "intermediate" stability. We note a similar result for ECTN≤8, while ECTN>8 was clearly linked to stability.

Interpreting the findings

In a perfect world, we would know absolutely whether a slope can be triggered or not. However, in reality, all studies exploring stability tests - including this one - must use other observations to infer slope stability. If the slope stability rating is wrong, which is inevitable for at least part of our data, then the test accuracy drops. For example, in our study we likely had at least some cases where observers did not see any signs of instability but the snowpack was still unstable and avalanches could be triggered. Similarly, there are also likely cases where

observers noted signs of instability on nearby slopes, but the slope being tested was in fact stable. These situations lead to a misclassification of the slope stability and have the potential to lower the correct classification by the stability test being evaluated. However, while these cases influence absolute values, it does not influence the observed patterns in Fig. 1. We can see this when we compare our much smaller Spanish data set, which was thoroughly quality-checked by the forecasters in Val d'Aran, to our U.S. and Swiss data sets, which both relied on observations submitted together with snow profiles. In Spain, the proportion of unstable locations was about 80% for ECTP≤23, and 8% for ECTN and ECTX in a data set with 35% unstable slopes (Fig. 2b). In the U.S. and Switzerland, absolute values and the shape of the curves were remarkably similar (Fig 2a and 2c). The only difference was that the proportion of unstable slopes for ECTP>22 was slightly above the base rate in the U.S. and slightly below in Switzerland.

Take-home points

The correlation between signs of instability and ECT scores clearly shows that the ECT is a valuable test for assessing snow instability. Our data confirms the findings in the Swiss study that including the number of taps in addition to the propagation portion of the results can improve the overall accuracy of this test. In line with the work of Techel et al. 2020 on Swiss data, we suggest the following terms for ECT results (see also Fig. 3).

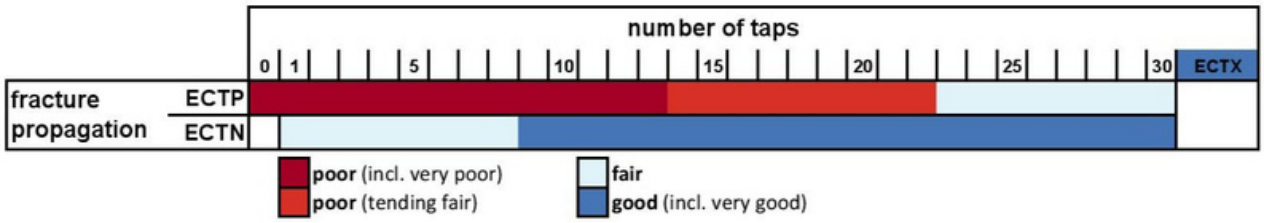


Figure 3: Relating ECT results to observed signs of instability in the surroundings in this data set. The stability class poor is split into two sub-classes, reflecting the trend seen in Fig. 1 for an intermediate number of taps.

A side note: Further results from a Swiss ECT study (Techel et al., 2020):

- Poor: ECTPs with easy - and to a lesser extent - moderate scores. In our data, these results are clearly correlated with instability,
- Fair: ECTPs with high scores and ECTNs with low scores. Our results suggest these values are more of a mixed bag in terms of their association with signs of instability.
- Good: ECTNs with moderate and high scores as well as all ECTXs. These results are most often associated with stable conditions.

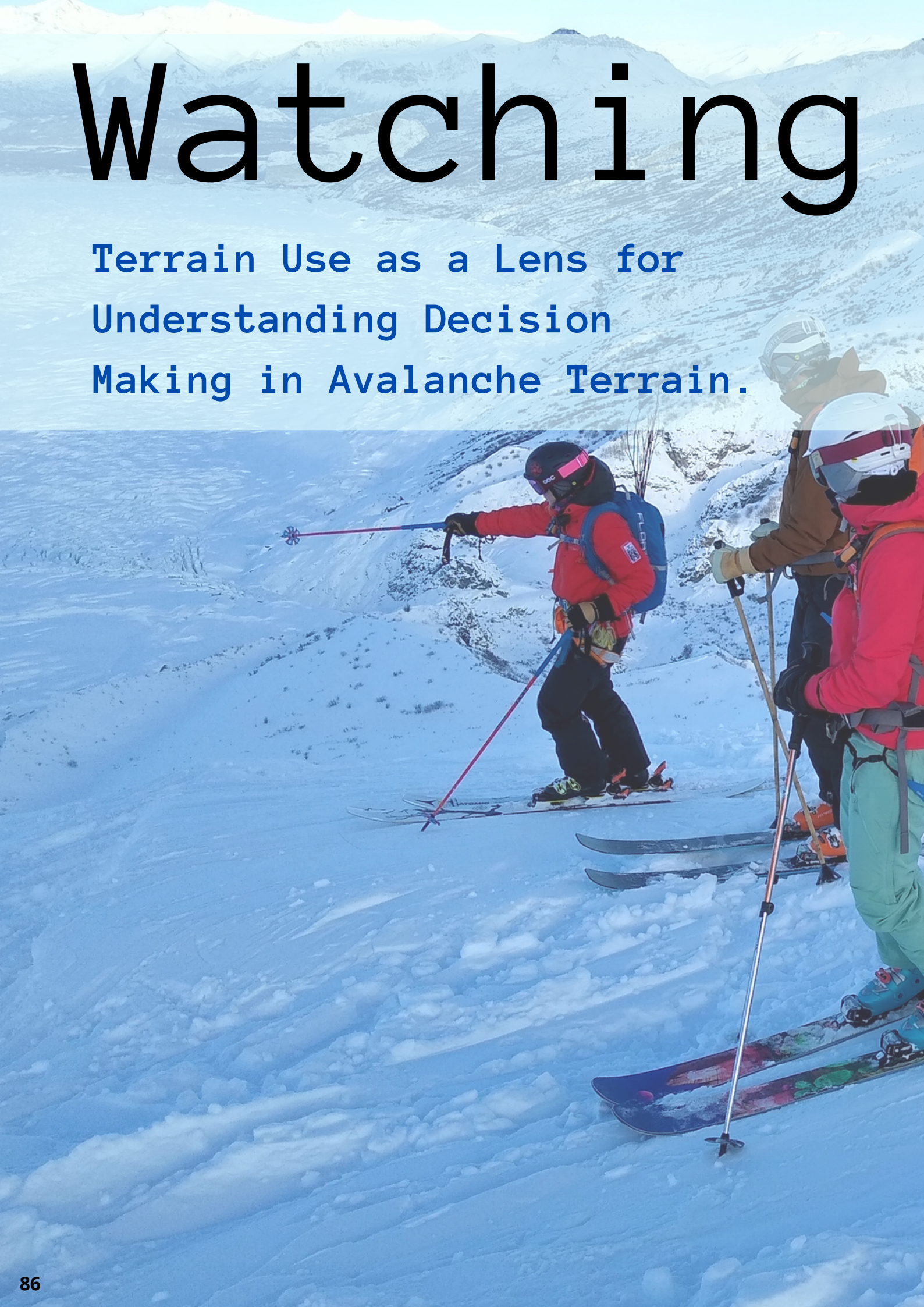
Even though this classification may help us interpret ECT results, several challenges remain: 1) selecting the right location for the test, 2) determining how representative that location is for the slope(s) of interest, and 3) understanding the inherent spatial variability of test results. Therefore, a single test with stable results should never be used as a sole indicator for stability, but should always be used in combination with many other field observations and additional tests, preferably in different locations. On the other hand, a single test with unstable results is enough to warrant extra caution.

Relying on the Swiss data set, which is included in our analysis, other relevant findings were noted:

- Performing a second ECT in the same snowpit was most useful when the first ECT indicated ECTP>14 or ECTN<10. Particularly in these cases, a second ECT could tip the balance towards indicating instability or stability.
- A direct comparison of ECT results with Rutschblock tests performed in the same snow pit showed that RB test results correlated better with slope stability than ECT results. In other words: if a RB test result indicated instability, more slopes were classified as unstable, compared to an ECT indicating instability. For results indicating stability, the opposite was observed.

Watching

Terrain Use as a Lens for Understanding Decision Making in Avalanche Terrain.



The Crowd

Jordy Hendrikx[1], Jerry Johnson[2], Andrea Mannberg[3], John Sykes[4], Diana Saly[5], Håvard Larsen[6], Andrew Schauer[7]

1 Snow & Avalanche Laboratory, Department of Earth Sciences, Montana State University
2 Political Sciences, Montana State University
3 School of Business and Economics and Center for avalanche research and education (CARE), UiT The Arctic University of Norway
4 Simon Fraser University Avalanche Research Program
5 Avalanche Canada
6 Norwegian Water Resources and Energy Directorate (NVE)
7 Chugach National Forest Avalanche Information Center

This article first appeared in the Canadian Avalanche Journal.

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 results 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 the 2012 ISSW 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 Proctor et al., 2013, Fitzgerald et al., 2016), John Sykes (a MSc student at the time, and now PhD student at Simon Fraser Fraser University) completed a focused survey to understand who, where, and how people used terrain in the Saddle Peak backcountry area 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.

John Sykes at the boundary of Bridger Bowl Ski area, conducting an intercept survey.

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. (2020) 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 the 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.

Timelapse 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). We were getting closer to understanding behavior, but it was the last step that gave us deep insight into the psyche of some skiers.

Diana Saly setting up her time-lapse camera, with the Saddle Peak backcountry area in the background (lefthand side, skyline ridge and face with cliff band).

Using 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.

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 note 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 questions may differ from real life behavior, 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 the 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, like we now have 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.

All photos credit: Jordy Hendrikx.

References to information about this research:

Fitzgerald, K.R., Kay, J.M., Hendrikx, J. and J. Johnson. 2016. Backcountry and sidecountry users: An intercept survey approach. Proceedings of the 2016 International Snow Science Workshop, Breckenridge, Colorado.

Haegeli, P., Haider, W., Longland, M., & Beardmore, B., 2010. Amateur decision-making in avalanche terrain with and without a decision-aid: A stated choice survey. Natural Hazards, 52, 185–209.

Hendrikx, J., Johnson, J., Mannberg, A., 2018. How do we really use terrain in the backcountry? A comparison between stated terrain preferences and Observed backcountry travel behavior. Proceedings of the 2018 International Snow Science Workshop, Innsbruck, Austria

Hendrikx, J., and Johnson, J., 2014. Using global crowd-sourced data to understand travel behavior in avalanche terrain. Proceedings of the International Snow Science Workshop, September 28 - October 3, 2014, Banff, Alberta, Canada

Hendrikx, J and J. Johnson. 2016a. Understanding global crowd sourcing data to examine travel behaviour in avalanche terrain. Proceedings of the 2016 International Snow Science Workshop, Breckenridge, Colorado.

Hendrikx, J and J. Johnson. 2016b. Tracking snowmobilers to understand travel behaviour in avalanche terrain. Proceedings of the 2016 International Snow Science Workshop, Breckenridge, Colorado.

Hendrikx, J. Johnson, J., and Shelly, C., 2016. Using GPS tracking to explore terrain preferences of heli-ski guides. Journal of Outdoor Recreation and Tourism, 13, 34-43.http://dx.doi.org/10.1016/j.jort.2015.11.004

Johnson, J., and Hendrikx, J., 2021. Using citizen science to document terrain use and decision making of back country users. Citizen Science: Theory and Practice. In Press.

Larsen, H.T., Hendrikx, J., Slåtten, M.S., and Engeset, R.V., 2020. Developing nationwide avalanche terrain maps for Norway. Natural Hazards. https://doi.org/10.1007/s11069-020-04104-7

Larsen, H., Sykes, J., Schauer, A., Hendrikx, J., Langford, R., Statham, G., Campbell, C., Neuhauser, M., Fischer, JT., 2020. Development of automated avalanche terrain exposure maps: Current and Future. Poster presentation at the Virtual Snow Science Workshop, Fernie, Canada, Oct. 4 - 6, 2020

Mannberg., A., Hendrikx, J., Johnson, J., 2020. Risky Positioning—Social Aspirations and Risk-Taking Behavior in Avalanche Terrain. Leisure Studies. https://doi.org/10.1080/02614367.2020.1831046

Mannberg, A., Hendrikx, J., Landrø, M., Stefan, M.A., 2018. Who's at risk in the backcountry? Effects of individual characteristics on hypothetical terrain choices. Journal of Environmental Psychology, 59, 46-53. https://doi.org/10.1016/j.jenvp.2018.08.004

Marengo, D., Monaci, M. G., & Miceli, R., 2017. Winter recreationists' self-reported likelihood of skiing backcountry slopes: Investigating the role of situational factors, personal experiences with avalanches and sensation-seeking. Journal of Environmental Psychology, 49, 78–85.

Procter, E., Strapazzon, G., Dal Cappello, T., Castlunger, L., Staffler, H. P., and Brugger, H., 2013. Adherence of backcountry winter recreationists to avalanche prevention and safety practices in northern Italy. Scandinavian Journal of Medicine & Science in Sports, 24(5). DOI: 10.1111/sms.12094

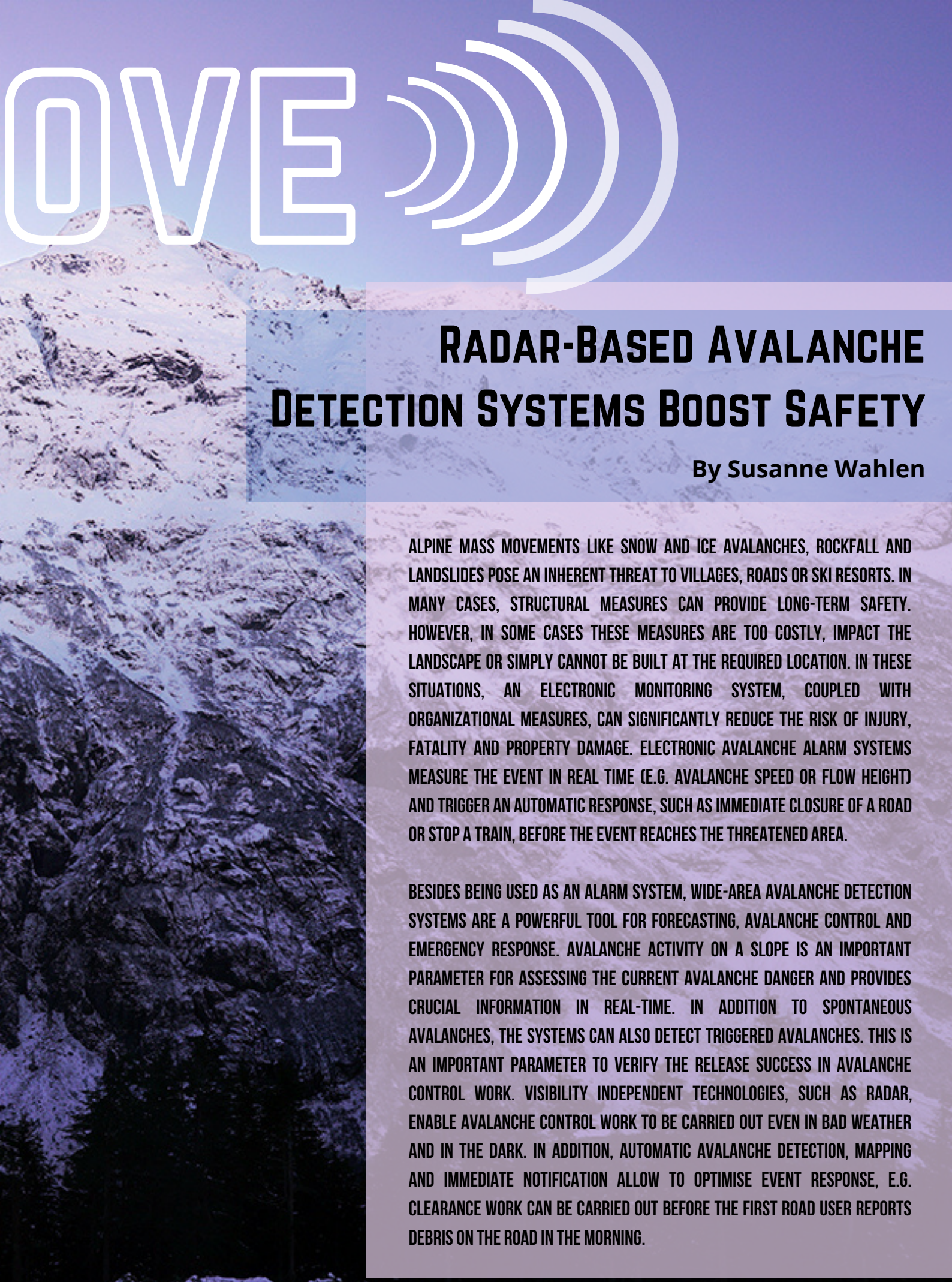
Saly, D., Hendrikx, J., Birkeland, K., Challender, S., Johnson, J., 2020. Using time-lapse photography to document terrain preferences of backcountry skiers. Cold Regions Science and Technology, 172, 102994. https://doi.org/10.1016/j.coldregions.2020.102994

Saly, D., Hendrikx, J., Johnson, J., and D. Richmond. 2016. Using time-lapse photography to monitor avalanche terrain. Proceedings of the 2016 International Snow Science Workshop, Breckenridge, Colorado.

Sykes, J., Hendrikx, J., Johnson, J., Birkeland, K., 2020. Combining GPS tracking and survey data to better understand travel behavior of out-of-bounds skiers. Applied Geography, 122, 102261. https://doi.org/10.1016/j.apgeog.2020.102261

RADAR L

An avalanche event at Bear Pass, British Columbia, Canada captured with the Geoprevent integrated 42 MP status and event camera.
Photo: Ministry of Transportation and Infrastructure MoTI



OVE

Radar-Based Avalanche Detection Systems Boost Safety

By Susanne Wahlen

Alpine mass movements like snow and ice avalanches, rockfall and landslides pose an inherent threat to villages, roads or ski resorts. In many cases, structural measures can provide long-term safety. However, in some cases these measures are too costly, impact the landscape or simply cannot be built at the required location. In these situations, an electronic monitoring system, coupled with organizational measures, can significantly reduce the risk of injury, fatality and property damage. Electronic avalanche alarm systems measure the event in real time (e.g. avalanche speed or flow height) and trigger an automatic response, such as immediate closure of a road or stop a train, before the event reaches the threatened area.

Besides being used as an alarm system, wide-area avalanche detection systems are a powerful tool for forecasting, avalanche control and emergency response. Avalanche activity on a slope is an important parameter for assessing the current avalanche danger and provides crucial information in real-time. In addition to spontaneous avalanches, the systems can also detect triggered avalanches. This is an important parameter to verify the release success in avalanche control work. Visibility independent technologies, such as radar, enable avalanche control work to be carried out even in bad weather and in the dark. In addition, automatic avalanche detection, mapping and immediate notification allow to optimise event response, e.g. clearance work can be carried out before the first road user reports debris on the road in the morning.

Radar traps for avalanches

Radar offers several advantages over other surveying techniques. First, it is not necessary to install sensors within the observed area, keeping both people and measurement equipment safe. Second, a single radar is sufficient to monitor areas of several square kilometers and thus several avalanche paths simultaneously. Third, unlike optical methods, radar measurements are largely unaffected by poor visibility. The atmosphere is mostly transparent to radar radiation and measurements are possible even in rain, snow fall or fog.

The radar applied for avalanche detection takes advantage of the Doppler effect and detects the frequency shifts caused by moving objects. Doppler radars are best known as speed traps used by police. But they can also be applied to measure other moving "masses", such as avalanches, rockfall or moving people as long as they move with at least a few metres per second. Since Doppler radars are sensitive to all movements within their target area additional criteria are needed to distinguish dangerous movements from "harmless" objects in motion, like helicopters or wildlife.

Avalanche algorithms

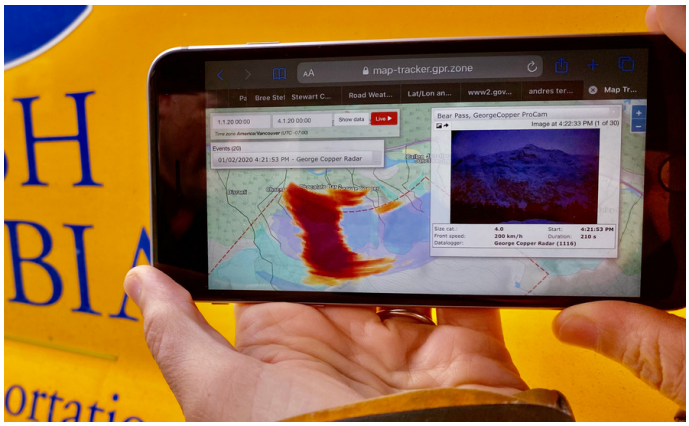
Since installation of our first Doppler radar in 2015 in Zermatt, Switzerland, we have detected more than 10,000 avalanches and 5,000 rockfalls worldwide. We have invested heavily in algorithm development for reliable detection and continuously adjust them with the growing data set. The algorithms determine avalanche position and speed, and estimate the size of the avalanche. It can also be configured according to local requirements. For example, if there are several gullies in the radar field of view, the software can be configured to only trigger an alarm if an avalanche of a certain minimum size is detected in one or more specific gullies. The detection of rockfall or people runs on the same radar hardware although with different settings. Depending on the range, it is possible to detect people and avalanches at the same time with the same hardware.

Customized system setup

The radars we apply have large antenna opening angles of about 90 degrees horizontally and up to 30 degrees vertically. Currently, maximum reach is 5 km for reliable avalanche detection. The avalanche radar comes as an integrated system including communication, control electronics, online data portal and, if necessary, power supply and alerting devices, such as barriers or traffic lights. We tailor the system to the local requirements and customer needs. The system design accounts for optimal visibility of the observed area, availability of power, communication, accessibility or hazard exposure of the site itself, e.g. to avalanches or rockfall.

Autonomous avalanche radar station with solar panels and fuel cell, high-resolution camera and communication devices at Bear Pass, BC, Canada.

If grid power is unavailable, we setup self-sufficient power supply using solar panels and fuel cells. The combination allows for reliable power supply even during short winter days and extended periods of poor weather. All our stations are equipped with communication devices and upload their data to our servers. Upon data processing, the avalanches are displayed in the online data portal. Detected avalanches are drawn on an online map along with the corresponding event images and avalanche characteristics, such as front speed, category and duration. Data transmission can take place via mobile phone network, fiber or ethernet or dedicated radio links or satellite, if needed. Radar data is processed locally and alarms are usually transmitted by dedicated radio links (traffic lights, barriers).



Avalanche visualization on an online map with event images and characteristics, such as time, duration, front velocity or category.

Avalanche radar pioneering in Zermatt

In 2015, we installed the world's first wide-angle Doppler radar avalanche alarm system for the municipality of Zermatt, Switzerland. Zermatt is one of the most famous

Avalanche radar installation in Zermatt for real-time detection of avalanches and immediate closure of the road sections at risk.

mountaineering and skiing destinations in Switzerland, with a year-round population of roughly 6'000 and a yearly overnight stay count of about 2 million. Zermatt is located at the end of the Matter valley with only one access road. While most tourists travel to and from Zermatt by train, residents and commercial vehicles rely heavily on the avalanche-prone road. Avalanches are released artificially by helicopter blasting when conditions permit. The avalanche alarm system acts as an additional safety measure for the road and has been in heavy use in the past few years. The system consists of two radar heads (upper and lower) and monitors three avalanche paths. Upon detection, it automatically closes the road sections at risk with five traffic lights and four gates.

An avalanche takes 30-75 s to reach the road (or 100-150 s for wet snow avalanches) depending on the altitude of the starting zone as well as avalanche size and speed. At the time of the first detection by the upper radar, it is not yet known whether the event will reach the road or not. This depends on a number of factors, amongst them the distribution of snow in the lower part of the avalanche paths. However, due to the limited warning time, it is necessary to close the road anyway, even if only temporarily.

To help the local authorities reopen the road quickly, we installed three road-side webcams with infrared light for day and night observation of the sections at risk. The lower radar allows for further simplification of the reopening process: If an avalanche detected by the upper radar cannot be verified by the lower radar, the road can be reopened automatically. For manual reopening authorised users can access the online platform via PC or smartphone and check the on-site situation via cameras upon reception of automatic alert messages and calls to their mobile phones. If the road is clear of debris, the road is reopened remotely. Since an on-site inspection was previously required, the webcams and remotely controlled traffic lights and barriers significantly reduced the time needed to reopen the road from about 45 minutes to 10 minutes.

Cutting-edge technology in the far North

Norway is characterized by hundreds of fjords along its coastline and mountain ranges with peaks above 2000 m above sea level. The steep fjord slopes are prone to natural hazards, particularly avalanches during winter. Many communities are located at the sea-side and heavily depend on roads along the shore for transport of people, goods and services. County Road 7900 in the Troms region, Northern Norway, leads through the avalanche-prone section of Holmbuktura and is the only access road to a small settlement and recreation area. Winter road safety was previously ensured by manual road closures based on avalanche danger assessments. Possible avalanche mitigation measures include a tunnel or an avalanche protection gallery, both with costs of more than 30 Mio Euro. Due to the relatively small volume of traffic, the Norwegian Public Roads Administration (NPRA) opted for a more cost-effective approach to improve road safety and chose an avalanche alarm system with real-time radar detection.

To ensure maximum warning time, the avalanche radar closes the road immediately upon detection. However,

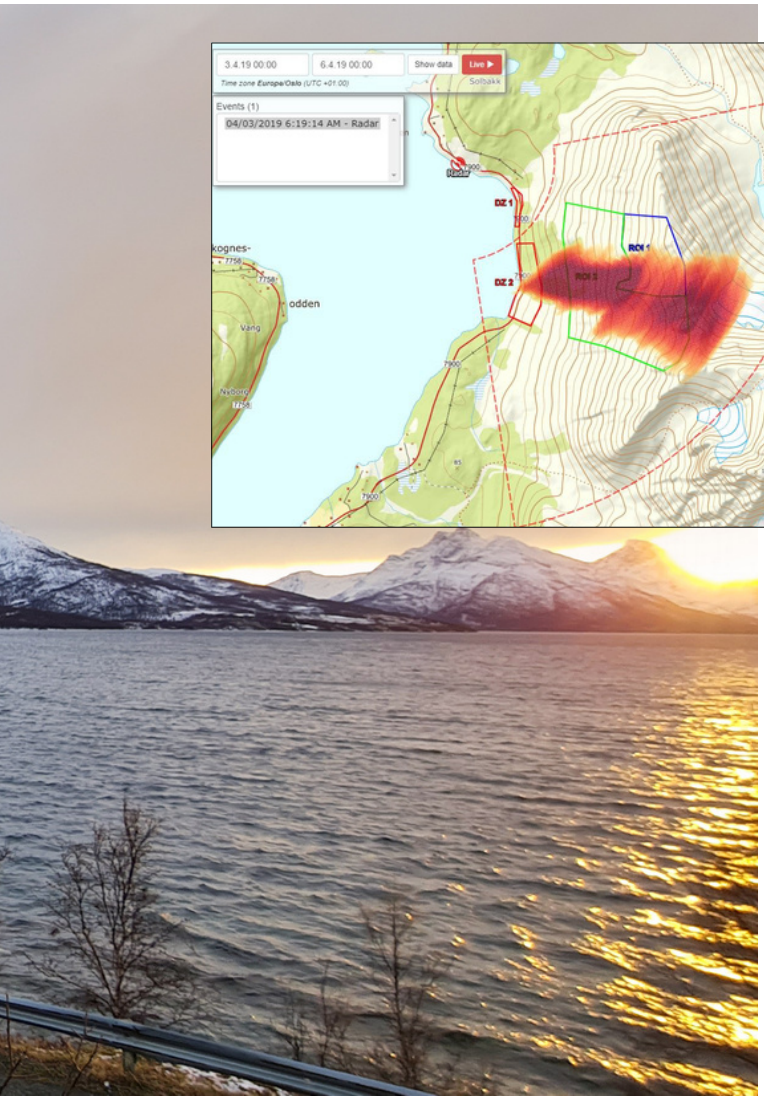
Two avalanche radars monitor the avalanche slope around the clock and detect avalanches in real-time and all-weather. Event images are automatically generated with a pan-tilt-zoom camera as well as a thermal camera. ***Inset:*** *Avalanche map of Holmbuktura Bay, Norway, with an event that reached the danger zone close to the road.*

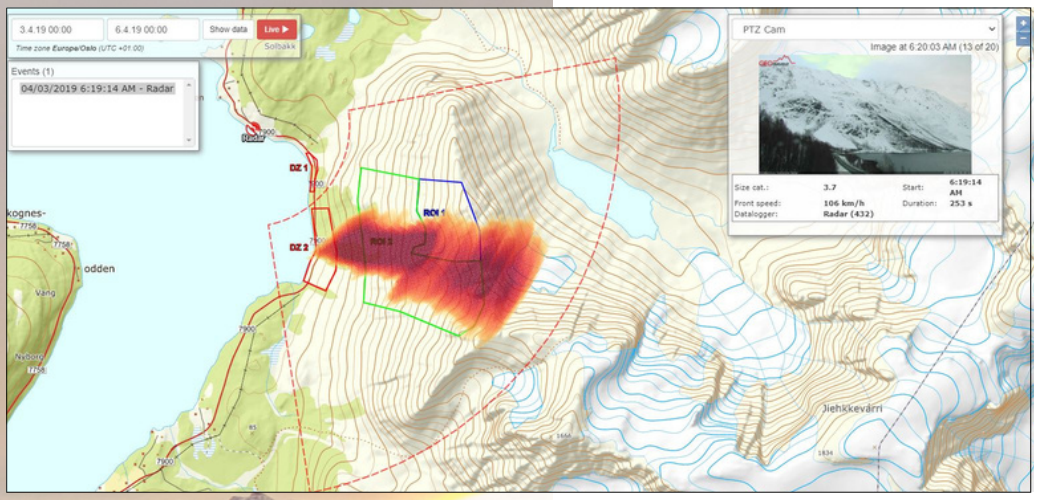
only a few avalanches really reach the road with most of them coming to a stop further up slope. For this reason, we implemented automatic reopening based on avalanche tracking and mapping with radar. Should a detected avalanche remain outside a predefined danger zone near the road, the radar system automatically gives the all-clear and reopens the road. This principle has proved very successful at other locations, such as the snow and ice avalanche alarm system Randa (Switzerland) with automatic closure/reopening of road and railway or the rockfall alarm system at Axenstrasse (Switzerland) with closure/reopening of one of Europe's main North-South traffic routes.

Reduction of road closures at Bear Pass

Similar conditions as in Norway can be found in Canada as well: avalanche prone road sections in sparsely populated areas with low traffic volume. The construction of avalanche sheds or tunnels would therefore not be economical. Highway 37A leads over scenic Bear Pass to the coastal town of Stewart, BC. A total of 72 active avalanche paths threaten the road on both sides and natural and planned avalanche events affect the highway between November and May each year. Avalanche mitigation includes preventative closures and targeted avalanche control. Nevertheless, the route should stay open and safe for residential and commercial traffic as long as possible.

In 2019, the Ministry of Transportation and Infrastructure (MoTI) decided to invest in an avalanche detection system to improve road safety and increase road availability during winter. Two sites were chosen that cover in total 10 avalanche paths at a distance of up to 3.2 km. System design was challenging due to its remote location and harsh weather conditions. Since there are neither electricity nor any means of communication in the area, we had to design the stations fully autonomously including an elevated relay station for radio communication to the nearest communication base at Stewart. Solar panels and a fuel cell provide power for the entire winter season and even more. 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 4m-snorkel, which also acts as 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





Avalanche map of Holmbuktura Bay, Norway, with an event that reached the danger zone close to the road.

methanol with automatic switches are stored in the cabinets, sufficient for the entire winter season.

The radar stations transmit detection data, high-resolution images, and system-relevant status reports over two different communication channels redundantly via repeater station to Stewart, where they are uploaded to our servers from the MoTI base station. The repeater station is the key hub of the entire system which also 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.

Previously, avalanche monitoring options for the avalanche team were limited to on-site observation during daylight and good weather. Using the automatic avalanche detection system, avalanche monitoring is now possible around the clock, in all weather conditions and via PC, tablet or cell phone. The teams receive event notifications in real-time by SMS or email and can check the online map for detailed event localization. Without the system many events would been inaccurately recorded. For example, if multiple avalanches occurred overnight in the same runout zone, they would 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 avalanche radar system 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 has been able to verify the accuracy of their forecasts and significantly reduce closure times of the highway by more than 40% of the annual average in the previous season.

Automatic people detection

The avalanche radar system can be extended to detect people or can be operated as a stand-alone people radar system. The detection of people is mainly applied for area monitoring prior to avalanche control work and is in operation in Zermatt and Belalp. (Switzerland). The radar detects people at a distance of max. 1500m, follows their movement and records their tracks on a map. This allows verification that the slope is free of ski tourers or the runout zone is clear of hikers.

GEOPREVENT currently operates over 130 stations for natural hazard monitoring, including snow and ice avalanches, glaciers, rockfall, debris flows, landslides and floods. Our stations are located in 11 countries in Europe, North and South America and Asia. While New Zealand is still to make it on to this list, the rugged and remote natural hazard prone locations of NZ would provide some exciting challenges for our applications.

Back Cover: *Event image of an artificially triggered avalanche above the only access road to Zermatt village as seen from the opposite valley side.*