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the AVALANCHE REVIEW

QUESTING QUESTIONS

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A3 STATEMENT OF PURPOSE

The American Avalanche Association promotes and supports professionalism and excellence in avalanche safety, education, and research in the United States.

A3 STAFF AND BOARD

the AVALANCHE REVIEW

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From our Volume 40 photo contest. Kakuhan Range of Southeast Alaska.
ALAN GORDON

ON THE COVER

This naturally triggered avalanche was the result of surface hoar and facets buried two weeks earlier. Guides Rich and Julie Marshall led skiers on an all-day tour through the alpine near Sentry Lodge BC, enjoying low angle powder and big views of big crowns. This was the only day with clear skies during a week with over a meter of new snow. PETER WADSWORTH

Eric Parker

ON BACKCOUNTRY

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FROM THE EDITOR

AMY PERTUZ

Here's the final issue in our 40th volume, 40.4. In most years, the April issue centers upon human factors, and this is no different. You will find a generous helping, however, of science-based stories inside, beginning with Erich Peitzsch's detailed work on dendrochronology that shows us how avalanche history can lead us to identify future trends. In the first of two timely pieces from our colleagues at the CAIC, Jason Kongisberg follows his curiosity to investigate historic Colorado atmospheric rivers and their subsequent avalanche cycles (page 21). He told me this about reaching out to pioneers in our field:

"It was a fun project to work on. I got to interview legends like Don Bachman, Art Mears, and Betsy and Richard Armstrong. I emailed back and forth with Jud quite a bit before he passed. Just to name a few. Really interesting!"

In the second CAIC contribution, Brandon Levy digs deep into Colorado archives to examine the weight of three consecutive non-freezing nights in wet slab occurrence. Is that pattern as important as others? See page 18 for his research and conclusions.

In this issue's array of human factors stories (starting on page 29), each highlights a particular quality of MIND that can cloud or clarify decisions—thus the QUESTING QUESTIONS tag line. In the opening story, Jeff Moskowitz goes deep into how a bear attack on a ski tour can lead us to be better prepared, mentally and physically, for other high-consequence, low-likelihood events. Next, in a rant worthy of his Stoic allusions, Jerry Johnson decries social media and lays out a path towards eudaimonia: literally, happiness through practical wisdom. Sarah Carpenter's look at manageability adds dimensions to our vocabulary while asking some hard questions about what is truly manageable. Be honest with yourself as you answer her; add to your margin. Mike Richardson once again brings his behavioral economics insight to the avalanche world, delving into mindsets attached to the continuum from EXPLORE to EXPLOIT. Next, perennial thinker Gary Kuehn submits the first essay in next year's focus on RESILIENCE, apt as A3 embarks on our RESILIENCE PROJECT. Stay tuned for details. Finally, Ryan Butler shares his master's thesis work of interviewing new backcountry travelers; understanding their mindsets and concerns can help us tailor our educational offerings accordingly.

Another trip back in time: Colorado, 1988.
PETER THURSTON

Changing the subject, Dougal McCarty takes us back in time to the early days of Big Sky ski area (page 24), into mountain and ski patrol hijinks and history. The message that shines through his story to me is the innovation, can-do attitude, and strength of the teamwork needed to learn, open, and mitigate any big mountain. Plus, they had SO much fun. Thanks for sharing, Dougal!

On the topic of teamwork, I worked some courses in the Pro track this year, and was deeply impressed by the caliber of both the student and instructor teams. It was a great privilege to spend time with both seasoned and aspiring professionals, each of whom brought great energy, curiosity, and professionalism to the table. I hope each of them is or has the opportunity to become a vital and contributory part of a high-functioning team, like our A3 team, where I'm continually amazed by the expertise and adaptability of my peers. Jayne "gets" our community and fits into her ED role better every day; Jen Reddy keeps us on track in so many ways; Erica Engle navigates the stormy seas of professional avalanche education with a steady hand; and McKenzie pulls out hidden meanings each time she lays out our stories. I use the TAR bully pulpit to unite the community. The A3 board supports and supervises us in furthering the mission. Thanks team for your energy and imagination in volume 40 of *The Avalanche Review*, plus so many other projects.

We hope that this TAR gives you plenty to digest over the summer. Our next deadline for submissions for the October TAR, 41.1, will be August 1, 2022.

— Lynne

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DEAR EDITOR,

Way back in 2009, the AAA Board adopted the Snowpack, Weather, and Avalanche Guidelines book, which set International units as the standard of care for avalanche work and record-keeping in the US, yet at forecasters' meetings, in public forecasts, in articles in *The Avalanche Review*, and even at International Snow Science Workshops in the US, I am dismayed to see US units still in widespread use.

It is embarrassing that whenever I travel or work abroad; my hosts obviously think we from the US are backwards, anti-science, and arrogant with our reliance on obsolete units that no one else uses any more. They are at first hesitant to broach what they think will be a difficult subject; then relieved when they find that I am fluent and agreeable; easy for them to communicate with.

The mix of units only creates confusion and lost time, and increases the chance of errors in conversion; as when the $125 million Mars Climate Orbiter was lost in 1999 when Jet Propulsion Laboratory workers used International units but Lockheed Martin engineers provided critical acceleration date in US units.

International units are based on water, and snow IS water; they are far simpler for us to use in our work than are the antiquated US units. We of all people should be leading the charge, pressing the National Weather Service and other state and federal agencies to change over. We should be leading with International units in our forecast products and snow reports, yet we are lagging.

The public and our coworkers are plenty smart enough to understand International units. Our snowsports public long ago made the switch from 6' 2" to 188 cm skis, from 49" to 125 cm poles, from 2500 cubic inch to 42 L packs, from 134 cubic inch to 2200 cc engines, and we easily know that 2200 cc is the same as 2.2 liters, because International units make sense. My highway, railroad, mining, and construction crews easily understand our reports and forecasts. Let's join the rest of the world!

Thank you
Bill Glude

BILL GLUDE is a longtime Alaskan teacher, guide, forecaster, researcher, and consultant who travels extensively.

FOR THOSE NEW TO THE CHANGEOVER TO INTERNATIONAL UNITS, HERE ARE A FEW EASY POINTS TO REMEMBER:

ON TEMPERATURE:

+40°C is desert-hot!

+30°C is hot enough if the humidity is up that most snow people are feeling a bit dizzy.

+25°C is a hot but still pleasant day.

+20°C is a perfect warm day or indoor temperature, equivalent to 68°F.

+10°C is a cool summer day or a crazy-warm winter day, equivalent to +50°F.

+5°C is too warm in winter, too cold in summer.

0°C we all know!

-2°C is still in the moist snow range.

-3°C is usually the threshold for dry snow.

-5° to -10°C is the range for a perfect ski day, with -10° being a bit chilly.

-15°C means add the warm layers; put the liner beanie, mittens, and big puffy in the rucksack.

-20°C is really cold, with -18°C being 0°F. Time to start the day with a liner beanie on, handwarmers, mittens, fleece pants, loosening the boots, and wearing one more layer!

Anything colder is serious cold! -30°C is -22°F, and -40° is the same in both systems.

ON DISTANCE AND SNOW DEPTH/HEIGHT:

There are 2.54 centimeters per inch.

A 2" x 4" board (if full dimensioned) is 5 x 10 cm, and 5 or 10 cm of new snow is still dust on crust, unless the crust soft.

15 cm of new snow is about 6", just enough to cushion the base if the snow is not too light.

20 cm of new snow is about 8", and we are starting to smile.

30 cm of new snow is a foot, and we are quite happy.

40 cm is about 16", and it is starting to feel deep.

50 cm is about 20", knee deep on a typical-size US adult male, and trail breaking is hard but we are stoked! Measure your own body to calibrate yourself; we are all different.

Anything more is a lot of new! A meter of snow is to the typical US adult male belly button, and two meters is a hand stretched over the head.

When we get into meters, think slightly longer yards. For estimating, yards are close enough.

ON WINDSPEED:

We should be sticking with meters/second, which is the official Système International (SI) speed unit, rather than getting sidetracked into kilometers/hour, as did many countries that switched early.

One of the beauties of m/s is that it is half of knots, which all who travel the water are good at estimating, and which are close enough to miles/hour that we can think of them as the same until we get to strong winds, where the error is enough to note, as in 50 knots equals 58 mph.

THERE'S YOUR ROADMAP FOR THE CHANGEOVER; NOW LET'S GO JOIN THE REST OF THE WORLD!

DEAR EDITOR,

When I open my mailbox and see the newest issue of *The Avalanche Review*, I always know that there is some quality time in my future. I really enjoy TAR with a cup of coffee and a blazing fire in the woodstove. The late winter edition 2022 was a comprehensive collection of excellent articles and industry updates. Amongst these articles, I was happiest to see Dr. Allison Sheets' article about hypothermia. We all know preventing avalanche deaths and accidents is a multi-faceted approach. I would like to ask A3 to bring more focus to the medical care aspect of avalanche safety and start a dialogue among us professionals on how to accomplish this.

Dr. Sheets' article is well written and shows the simple to understand Swiss model for hypothermia recognition and care. In my nearly four decades as a paramedic, I have seen the vicious cycle of what hypothermia can do to a human. Yet, when recognized early and treated correctly, outcomes can be positive. As a "tongue in cheek" comment when asked when I started as a paramedic. I replied, "I thought I was in line for the Van Halen tickets, but got into the paramedic school entrance exam line by mistake." Resuscitation of the lifeless person has come a long way since then. The proven resuscitation practices that have yielded the most are an organized team approach, early intervention, and high-quality C.P.R. I have always felt that avalanche safety education has missed the medical care aspect. Could this be our next step in improving safety in avalanche terrain? I would say yes.

Saving a life happens when someone is present, recognizes the problem, and if early, can amazingly turn the insidious tide of critical illness. But most of all they must quickly act in the appropriate manner to treat the ABCs. The chain of survival is only as good as its weakest link. Let's not forget to give our recreational users basic CPR/ first aid skills and to foster a medical culture of excellence among our industry professionals. Medical studies have proven that early interventions work. Avalanche terrain is so far from an organized prehospital care system that our efforts should be focused on those that are immediately present after the avalanche accident.

With sincerest thanks,
—Heiko Stopsack
Hood River Crag Rats — Mountain Search & Rescue Team Member
King County Medic One / King County Sheriff Air Support Unit
Senior Paramedic / Rescue Specialist

PRESS RELEASE:

Safeback Announces SBX System

Designed to extend the survival window under an avalanche from 15 minutes to 90 minutes

After five years of prototyping, development, considerable testing, patent and certification processes, we are finally able to announce more details about our product.

The Safeback SBX system, when activated, will retrieve clean air from the snow through a filter in your backpack, and actively pump it up through the hose systems in your backpack straps. Clean air will diffuse through dense avalanche snow adding air with normal oxygen levels to the breathing area. As an added effect the carbon dioxide is diluted.

The field research and tests show that this unit can provide enough clean air to extend the expected survivable period of time buried under an avalanche from 15 minutes to 90 minutes.

Field testing and certification has been a very important part of the development process, and Safeback has been fortunate to be supported by the Norwegian Armed Forces with a development contract administrated by the Armed Forces Research Establishment. One of these tests involved live breathing tests under snow, and another with a mannequin and mechanized breathing system to simulate real O2 and CO2 levels. Additionally, the Mountain Medicine Research Group at University of Bergen has performed independent studies related to the problem that Safeback's product aims to solve.

"Snow is porous, so even in a large avalanche with dense snow conditions, the Safeback system can deliver fresh air to your nose and mouth so long as your mouth and nose are at or within 25 centimeters or 10 inches from the nearest outlet on one of your shoulders."—Tor Berge, CEO of Safeback

By integrating directly into backcountry airbag and freeride backpacks, we can ensure that the unit is protected from the forces during an avalanche, and that the hoses stay securely in place near the user's mouth and nose. Our system is the first to use electronics to actively provide clean air to the buried person. Much like electrical airbags, the SBX is fan-based and battery-powered in order to be reliably and repeatedly used. The system uses replaceable, non-chargeable batteries due to their higher reliability in the cold. With batteries, the whole system weighs roughly 450 grams.

The Safeback SBX is activated by pulling firmly on the T-shaped handle on your backpack—very similar to those used in airbag systems. This means that the user will not need to have any equipment in their mouth while they are navigating in steep terrain and can activate their device if they are in immediate threat of being caught by an avalanche. In cases where backpacks have both airbags and an SBX, the activation wires for both can be integrated into a single activation handle.

We are planning to launch in the winter season of 2023-24, pre-integrated into packs from 3-4 backcountry pack producers. Our goal is to maximize the number of lives we save with the SBX system, so we will not offer any single producer exclusivity over our product.

For more information, contact:
Safeback—Avalanche Survival Gear:
Tor Berge, CEO,
tor.berge@safeback.no

METAMORPHISM

Bridger-Teton Avalanche Center Updates:

LONG-TIME BTAC DIRECTOR BOB COMEY RETIRES

COURTESY OF BOB COMEY

Bob Comey fell in love with skiing at an early age and in eighth grade decided he would move to Jackson Hole. He began backcountry skiing in the 1970s in the White Mountains of New Hampshire, on Mt. Katahdin, and in the Longfellow Mountains of Maine. In college he devised a plan to become an avalanche forecaster by studying meteorology, climatology, and graduate level courses in glaciology and glacial geology at the Quaternary Institute at the University of Maine. During his first ten years in Wyoming, he was a ski bum, ski instructor, backcountry guide, avalanche educator, and ski racer.

In 1988, Bob's plan started to become reality when he was offered a ski patroller job at the Jackson Hole Mountain Resort (JHMR). A quick advance into an avalanche forecasting position for the resort and into a backcountry avalanche forecaster position for the Bridger-Teton National Forest Avalanche Center (BTAC) ensued. Those simultaneous careers lasted 30 years. At the resort he was an avalanche hunter armed with an arsenal of resources that included artillery, unlimited explosives, and a crack team of 40 to 60 ski patrollers. Every morning's forecast was immediately tested, and feedback from those efforts, as well as daily observations and field measurements from snow study plots, were combined to effect hazard forecasting tasks 24/7. In the backcountry this knowledge was used to avoid avalanche hazards and gain essential data. Bob's lifelong mission was to understand the snowpack and communicate that information to co-workers and the public.

Weather and avalanche forecasting was rather primitive in the early 1990s. At 5am forecasters would count tick marks on strip charts for each mile of wind that passed by wind sensors and each hundredth of an inch of moisture that fell through gauges at precipitation stations. Before leaving for the day forecasters would top off ink levels, replace chart paper, and manually rewind the rows of Esterline Augus strip chart machines. Weather forecasts from the National Weather Service would arrive via TELEX. Phone calls were made on a WATS line. The public faithfully called a telephone hotline to hear the daily backcountry avalanche forecast.

As a licensed professional geologist, Bob supplemented his work in avalanche science by spending summers on geophysical field crews, prospecting for oil and gas. Later he opened an environmental engineering office to investigate and design systems to remediate sites from impacts to soil and groundwater from leaking underground fuel storage tanks.

Retirement will be spent visiting daughters who live in Bozeman, his mom who turned 99 on February 26, and on a perpetual honeymoon with his new wife. That future will include many games

This season's telemark champion, Bob Comey.

of pickleball, hikes, bikes, naps, and travel. Casual late mornings will be a priority.

What he values most from his time in the avalanche world was the opportunity to work with incredibly talented cohorts, colleagues, and a host of memorable characters. He deeply values the relationships that developed with these individuals and with professionals at entities such as the Wyoming State Trails Program, the National Weather Service, the American Avalanche Association, other avalanche forecasting programs, and the non-profit organization that supports the operations of the BTAC.

Some of the many highlights of his career include the Teton February 1986 avalanche cycle that redefined the boundaries of hundreds of major avalanche paths and was likely a 100-year event. Innovative collaboration and experimentation permeated a period where sled bombs were developed, bomb trolleys refined, and fixed-point exploders inserted into avalanche starting zones. Bob was there when mentors Jim Kanzler and Larry Livingood first put a daily avalanche hazard forecast onto something called the World Wide Web. Later, Carol Peck and Chris McCollister blended geographic information system technology and advanced web programming knowledge with the skills of Patrick Wright to create displays of essential avalanche information on the BTAC website. Using funding from the National Science Foundation, Bob also worked closely with electrical engineer Ernie Scott, who used his signal processing expertise to develop arrays of infrasonic sensors that detected avalanche movement in near-real time. Federal Highway Administrative Funds and trails fees expanded the Bridger-Teton Avalanche Center's burgeoning and beneficial partnership with the winter motorized community. The daily grind of avalanche forecasting would not have been possible without support from Mike Rheam and Dan Judd.

Along the course of Bob's career, AT gear, splitboards, mountain sleds, a destructive avalanche size scale, social media, sophisticated weather models, and major advances in database and computer technology entered the arena. In addition, he participated in over 60 investigations of avalanche fatalities.

Thanks, Bob, for your many early mornings and countless contributions to the avalanche community!

WELCOME TO THE TETONS FRANK CARUS

BY EVAN ROBINSON-JOHNSON

This piece first appeared in the Jackson Hole News and Guide *on February 16, 2022, and is reprinted with permission.*

Frank Carus is the new director of the Bridger-Teton National Forest Avalanche Center. Carus was previously with the Mt. Washington Avalanche Center in New Hampshire, where he was Director for 3.5 years.

Fresh from the East Coast's gnarliest weather station atop Mount Washington (a paltry 6,288 feet, compared with the Grand Teton's 13,775, but still the site of some of the highest wind speeds in the world) Carus dove eagerly into his new role as interim director, following longtime director Bob Comey's retirement. Comey stuck around to ease the transition, but Carus was still inundated at the start.

"I'm drinking through the fire hose," he said last month, sitting down with the News&Guide at the Bridger-Teton headquarters. Carus was officially hired as full director in February 2022.

Back in early January, snowstorms were still keeping things interesting on the slopes and Carus was managing new employees, stations, and tracking systems. The mountains weren't new though.

A former climbing bum who climbed El Capitan in Yosemite National Park at 19, Carus first came to the Tetons as an Exum guide in 2008. He joined the U.S. Forest Service three years later, which balanced his technical skills with an understanding of what makes American public lands unique. While his phone still pings with notifications of slides in the White Mountains, fresh adventures in Jackson Hole beckon.

"This region has always spoken to me," Carus said. "I love technical climbing and technical ski lines, and we have that here in spades. This is basically the Alps without lifts."

He also takes his responsibilities seriously, knowing a mis-forecast can be deadly. Reliance on forecasts can also be deadly, Carus is quick to add.

"We're forecasting; we're not predicting," he said. "We can't control where someone goes in the terrain."

HUNTING PHILOSOPHY

Forecasting slides or "avalanche hunting," as Carus calls it, is a balancing act. People go tone deaf to "sky is falling" high-risk warnings, not unlike the county Health Department's "high risk" COVID-19 tracker, which was originally respected but then shrugged off.

"We're not the first government agency to learn that," Carus said. "The second time you issue an

KATHRYN ZEISIG

avalanche warning or a hurricane warning and nothing happens, people stop listening."

That said, there's still an imperative to issue timely, accurate assessments, especially in a coverage region like the Bridger-Teton National Forest, where hundreds of recreationists venture in small parties or with guides every day. Although some people "use forecasts to shrink their margins and get killed," Carus said, the vast majority of them rely on fresh reports to make safe plans.

A simple message people sometimes forget is that low danger doesn't mean no danger.

"Technically, we should see an avalanche during low periods," he said. "Otherwise, we're missing it."

That's one reason Carus is already quite grateful for the Jackson Hole community. With so many savvy recreationists touring the backcountry, the Avalanche Center receives a bevy of reports, which help staff paint a more accurate picture of snow conditions.

INSTITUTIONAL SUPPORT AND EXPECTATIONS

Backed by the U.S. Department of Agriculture, the U.S. Forest Service affords forecasters the unique opportunity to make life-or-death recommendations with the security blanket of legal protection.

"We have a discretionary function to basically provide our opinions to people," Carus said.

Carus still remembers the first time his boss asked him to pull a handwritten advisory forecast he had posted at Mount Washington's Harvard Cabin. An adventurer had perished, and the forecast was considered public record—evidence in the case.

"It was one of those moments where you're like, 'Oh wow, this is serious,'" Carus said.

STARTING AT A ROPE-TOW MECCA

Before his summer stint in Yosemite, Carus was a bright-eyed skier from Atlanta. The skiing was up by his grandparents' home in Michigan at a rope-tow mecca known as Apple Mountain. "It's basically big dirt piles from irrigation ponds, and they pile it up, I think it was like several hundred vertical feet," Carus said. "I remember Spademan bindings and just zipping up and down." That slope planted the seed, and subsequent family trips to larger vistas helped nurture Carus' passion. He attended the closest college to year-round rock climbing, studying geography and the environment before moving to New England for a job with the International Mountain Climbing School in North Conway, New Hampshire.

Eventually he found his way to the Mount Washington Avalanche Center in New Hampshire, the oldest backcountry forecasting program in the country, which he directed from 2018 to 2021. As backcountry use exploded, Carus' mission remained the same: Help people find good snow and have a good time, but also make sure they go home at the end of the day.

Unlike Jackson, where people move for a lifestyle of recreation, Carus frequently greeted skiers in Tuckerman Ravine who bopped out on a day trip from Boston.

"I can't imagine a more ripe place for looking at human behavior and its interaction with steep mountain terrain," he said of that time.

Carus has swapped that canvas for the 10,000-foot variety, but he's charmed by similar serendipity in both locales.

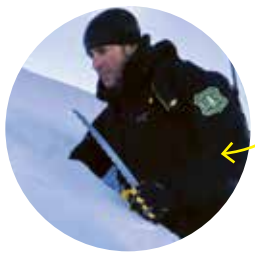
"A lot of this is new here for me," he said. "Every day is pretty fresh, and it's pretty fun to see the terrain evolve as winter progresses."

"That's something that I always appreciated on Mount Washington, just being able to go to the same slope week after week through the season and see how it evolves."

EVAN ROBINSON-JOHNSON covers issues residents face on a daily basis, from smoky skies to housing insecurity. From New England, he has settled in east Jackson and avoids crowds by rollerblading through the alleyways.

OTHER BTAC UPDATES

Long-time forecasters Mike Rheam, Assistant Director, and Lisa Van Sciver (position funded by the GTNP Foundation), are with the BTAC again this season. In addition to new Director Frank Carus, John Fitzgerald, Alex Drinkard, and Drew Gibson joined the team.



John Fitzgerald comes to the BTAC most recently from the WYDOT avalanche program. His diverse work background includes the roles of educator, cat, heli and human-powered ski guide, program manager, and both backcountry and highway forecaster. He has spent the majority of his career in the Teton and Togwotee Pass zones. For several years he migrated north to Alaska for the winter and spring seasons where he worked as a forecaster for both the Chugach Nat'l Forest Avalanche Center as well as Valdez Heli Ski Guides on Thompson Pass. In joining the BTAC, John is excited to have the opportunity to help build upon past success while striving to innovate and improve the program going into the future.

Alex Drinkard joined the Bridger-Teton National Forest last winter on the snow ranger program and will be expanding his duties assisting the avalanche center this winter. Originally from Spokane, WA, Alex grew up in the mountains and was fascinated with remote backcountry environments at an early age. His career with the US Forest Service began with seasonal work in silviculture while obtaining a BS in Environmental Science from Portland State University in 2016. From there, he transitioned to wildland fire which enabled Alex to spend countless days each winter in the backcountry of beautiful British Columbia and gain extensive motorized and non-motorized recreational experience. Alex has Professional Level 1 avalanche certification and is excited to blend his scientific understanding and risk management experience to pursue a career in the snow and avalanche field.

Drew Gibson joins the BTAC team as a seasonal avalanche forecaster this season. Drew gained extensive experience in forecasting at Copper Mountain and New Zealand's Temple Basin. Drew grew up in the Colorado mountains where he decided ski patrolling was better than college. Finding his place among the team he quickly became an educator and mentor to younger staff. In addition to ski patrolling, he has worked as an avalanche educator, guide and backcountry forecaster in NZ. Passionate about rescue he volunteered for many years with the Summit County Rescue Group and held a board member position with the Colorado Rapid Avalanche Deployment nonprofit, training rescue dogs and humans alike. ⬢

WILDERNESS MEDICINE REFERENCE APP

BY KAREN LAPIDES

The Wilderness Medicine Reference App is an offline app designed to provide a convenient reference for the recognition, treatment, and evacuation considerations for traumatic injuries, environmental illnesses, and medical conditions that may be encountered while on a winter backcountry tour.

In addition, significant content is dedicated to the subjective decision-making errors that contribute to most incidents and near misses in winter backcountry endeavors, as well as positive habits that can replace those. Studies have shown that teaching about human factors contribution to accidents and having that knowledge alone does not favorably influence decision-making errors significantly for most people.

The Wilderness Medicine Reference attempts to address this gap in classroom knowledge and field application by the use of checklists to be used before, during, and after an excursion in order to ritualize attention to these subjective factors. The checklists can help recognition of these influences at the appropriate time to mitigate their subliminal leverage as well as provide a structure for decision-making around them. The checklists capitalize on the training many backcountry enthusiasts already have, but the temptation of the perfect 38-degree snowfield can cause us to discount.

Each of the medical sections (environmental illness, traumatic injuries, medical conditions) is broken into the following sections: background educational information, assessment, treatment, prevention, and evacuation considerations. All content in the app is heavily referenced and reviewed by experts in the respective fields. Live links out of the app are provided for much of the content.

While the app is probably best suited to those with some wilderness medicine training, even those with no medical training can benefit from the medical part if they walk through the patient assessment chapter prior to treating a patient. The subjective decision-making errors content is appropriate for everyone, from experienced guides to beginners.

Content included that is specific to the winter wilderness context:

1. Hypothermia in the trauma patient.
2. ICAR avalanche resuscitation guidelines.
3. Realistic frostbite, hypothermia, and high altitude decision-making considerations.
4. Case studies of several difficult situations exacerbated by influence of hypothermia.
5. Tips for administration and storage of medications that may freeze in a winter environment such as albuterol nebs, epinephrine for allergic reactions, insulin, and glucagon.

There is also a Pain Management section as well as basic Medication Reference. Finally, there are lists for different First Aid Kits based on activity.

Practicing medicine in an austere outdoor environment is an entirely different proposal than inside a warm ambulance or emergency room. Fortunately, most backcountry skiers never need a medical reference, especially enthusiasts that focus on prevention habits. However, if you do land in an emergency situation, the information in this app can help you recognize and deal with it in a more informed, effective, and thorough manner. All of us have needed a reality check when confronted by subjective decision-making influences; the checklists within this app can help prompt necessary and mitigating discussion with our partners.

The Wilderness Medicine Reference app is available for $1.99 on Apple and Google Play stores.

KAREN LAPIDES is a paramedic living in Breckenridge, CO. She teaches wilderness medicine courses and emergency medicine.

NATIONAL AVALANCHE SCHOOL UPDATE

BY MICHAEL FERRARI

The next classroom session of The National Avalanche School (NAS) will be held October 23–27, 2022, in the Salt Lake area at the Embassy Suites in South Jordan. The NAS is one of the longest running avalanche education programs in the country. The NAS offers comprehensive avalanche training specifically designed for ski area operations. The NAS is held in two parts—a four-and-a-half-day classroom session and a four-day field session held in the winter. Graduates earn an A3 Pro1-NAS designation; which exceeds the A3's basic Pro 1 requirements. Participants must attend and successfully pass the classroom session in order to attend one of the field sessions. The field sessions are administered by the American Avalanche Institute.

The NAS classroom session gives students an unprecedented opportunity to interact with many of the industry's leading experts. NAS instructors have written the books, developed the science, and applied industry best practices in their instruction and in their own operations. The instructor cadre includes Bruce Tremper, Karl Birkeland, Simon Trautman, Ethan Green, Paul Baugher, and Dale Atkins to name a few. No other avalanche educational experience in the United States offers this level of interaction with nationally recognized experts. Students develop lifelong professional relationships and return to their home ski area with valuable skills,

Doug Chabot and Mark Staples get the band back together as NAS instructors. JENNIFER LARSON

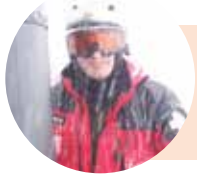
knowledge, and information to share with others. While the school is oriented towards ski patrollers; avalanche forecasters, avalanche center observers, USFS permit officers, DOT workers, and guides and educators can also benefit from attending the NAS as it provides students with a solid foundation of avalanche fundamentals.

I attended the National Avalanche School Classroom sessions in 1997 and 1999 in Incline Village and the field portion those same years at Squaw, Alpine ,and Sugar Bowl. I had such a great experience the first time that I decided to attend a second time. My first year at the NAS gave me the start of my formal avalanche education and provided the foundation of a 30-year career

NAS Instructor Mike Rheam facilitating a group exercise. JENNIFER LARSON

managing avalanche terrain in a ski area operational context. I considered many of the instructors at the schools I attended as mentors, including Doug Richmond, Larry Heywood, and Paul Baugher. I truly believe that the NAS is one of the greatest opportunities for facilitated mentorship in the ski and avalanche industry.

If you are interested in attending or sending staff to attend the 2022 classroom session of the National Avalanche School more information can be found at https://www.avalancheschool.org/ or by emailing me at ferrariski@live.com. The cost is $570.



MIKE FERRARI is Program Director of the National Avalanche School

KBYG: The Next Generation

BY CHAD BRACKELSBERG

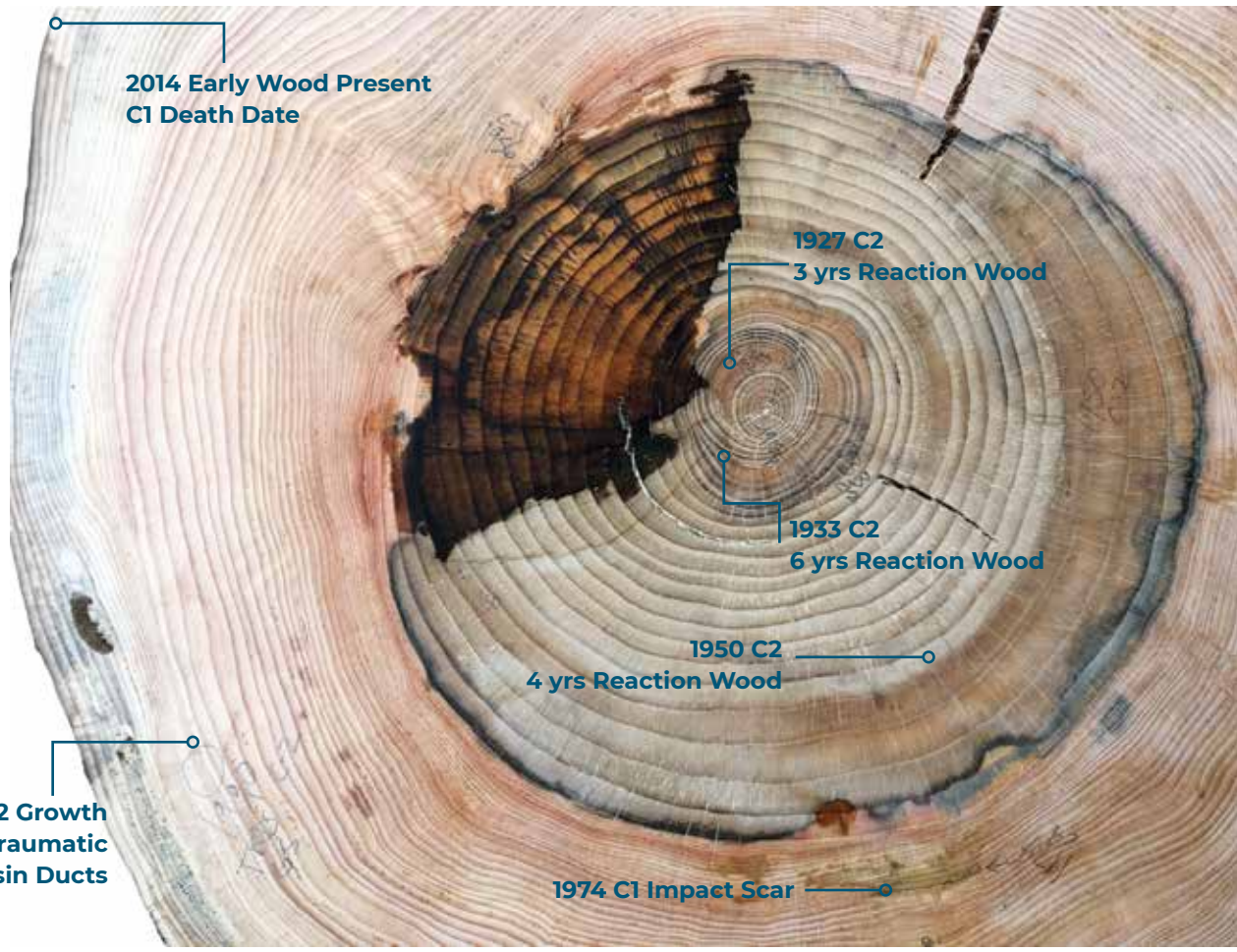
The Utah Avalanche Center (UAC) is excited to announce the next generation of the **Know Before You Go (KBYG) Avalanche Awareness Program** scheduled for release in October 2022. KBYG was developed by the UAC after the December 26, 2003, avalanche near Sundance Ski Resort in Utah that killed three teenagers (https://utahavalanchecenter.org/avalanche/24261). In 2015, the program was redesigned in partnership with Colorado Avalanche Information Center (CAIC). For the third generation of KBYG, we are proud to partner with the CAIC, Northwest Avalanche Center, National Avalanche Center, and Avalanche Canada. The program updates are made possible by support from Mammut, Backcountry, KUHL, RECCO, and numerous foundation grants.

The new program consists of new presentation materials, new videos being created in partnership with Sherpas Cinema, new online learning courses, and a new website. The new KBYG program is being developed for both school-age children 13 years and older as well as adults. The goal of the program is, "to motivate people to learn more about avalanches" by teaching them that avalanches are dangerous, showing who is affected by avalanches, and teaching that avalanche education is the key to staying safe. The program will use curiosity and interactivity to help accomplish its goals.

If you are a current KBYG presenter or if you would like more information about the KBYG program please email info@kbyg.org. Be sure to follow KBYG on Instagram (@KBYG.avy) and Facebook (@KBYGavalanchesafety) for more information.

USING TREE-RINGS TO UNRAVEL AVALANCHE FREQUENCY AND ASSOCIATED CLIMATE DRIVERS

BY ERICH PEITZSCH, JORDY HENDRIKX, GREGORY PEDERSON, KARL BIRKELAND, DANIEL STAHLE, & DANIEL FAGRE



A tree ring sample from Glacier National Park, Montana. The annotation shows various types of avalanche signals and associated quality ratings through the lifespan of this sample. This tree (sample #18) is a sub-alpine fir (*Abies lasiocarpa*) from the 54-3 avalanche path in Glacier National Park that was 96 years old (1918-2014) when it was uprooted and killed by an avalanche in 2014. D. STAHLE, USGS.

Understanding avalanche return intervals is critical for local and regional avalanche forecasters, transportation agencies, and land use planners. Carefully documenting past avalanche frequency and magnitude helps us understand current and future avalanche behavior in the face of climate change. Long-term, reliable, and consistent avalanche observation records are necessary for calculating avalanche return intervals, which can be used in infrastructure planning and avalanche forecasting operations. However, such records are often sparse or non-existent in many mountainous regions. This is especially the case for large infrequent events. To overcome this issue, we can use dendrochronology, or the study of tree rings, to infer the natural (i.e. expected) avalanche frequency at different scales, from the individual path to an entire region (*Figure 1*). Even in regions with historical records, tree-ring dating methods can be used to extend or validate uncertain historical avalanche records.

Trees are susceptible to damage from avalanches and they record the effects of this disturbance (*Figure 2*). An avalanche may cause wounds on the trunk or branches. It can also locally destroy the growing part of the trunk, or cambium, and disrupt new cell formation. The tree then produces callus tissue, and the cambium cells overgrow the injury, forming a "scar" on the tree-ring. Other types of disturbance within tree rings from avalanches include reaction wood and traumatic resin ducts[7].

Recently, we used tree-rings to:

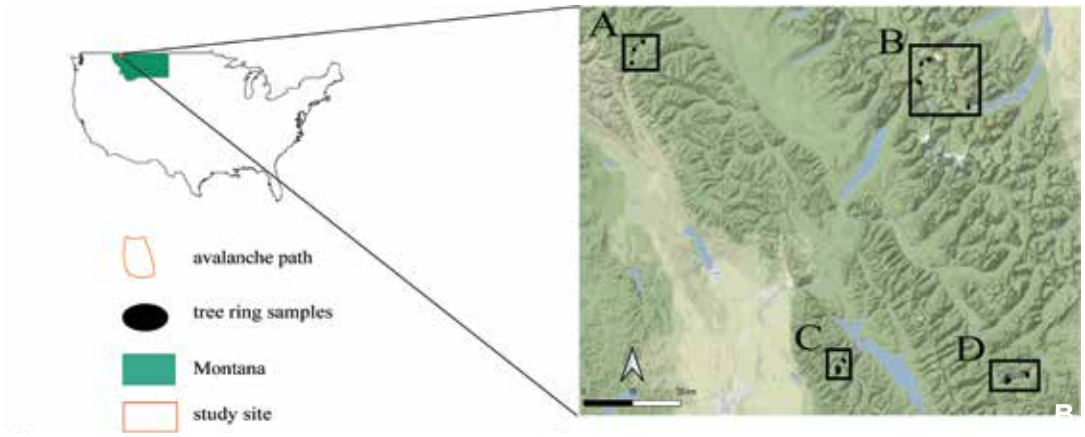
- reconstruct a long-term avalanche chronology in the U.S. northern Rocky Mountains;
- examine the frequency of large magnitude avalanches at the regional and individual avalanche path scales;
- identify specific seasonal climate or atmospheric circulation variables that contributed to years with large magnitude avalanche events across the U.S. northern Rockies region; and
- estimate widespread extreme avalanche cycles in Colorado, USA (new project).

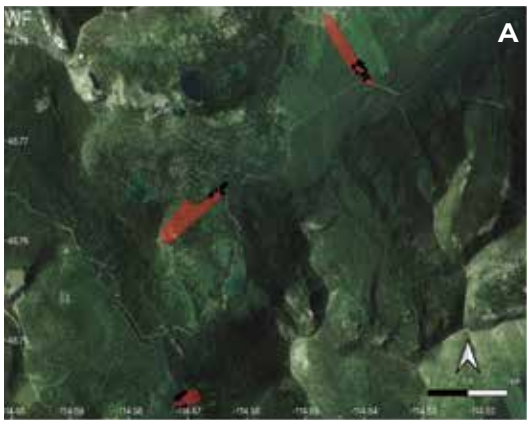
We defined large magnitude avalanches as approximately size three or greater[8],which may or may not run the full length of the avalanche path. In this article, we broadly present our methods, highlight a few key results of our work in the U.S. northern Rocky Mountains, and discuss our objectives for ongoing work in southeast Alaska and Colorado.

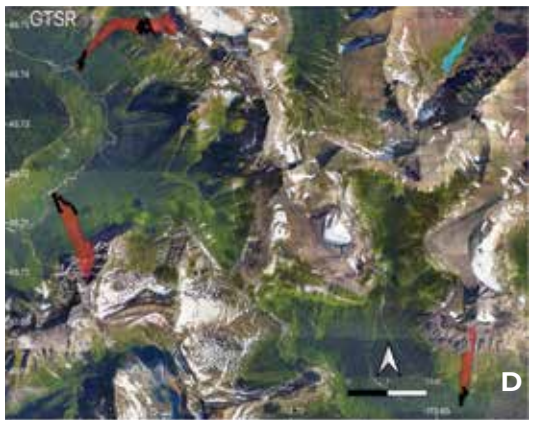
CHAINSAWS, MICROSCOPES, AND STATISTICS

In each of our study areas (Montana, Alaska, and Colorado) we strategically sampled avalanche paths in distinct zones to examine how those different zones might compare to each other at a larger regional scale. Our sampling strategy[9] helps us understand the nature of the problem, the scale at which measurements should be made, and how we can estimate the measurements across space.

This story first appeared in The Avalanche Journal, *Volume 128, winter 2021–22*







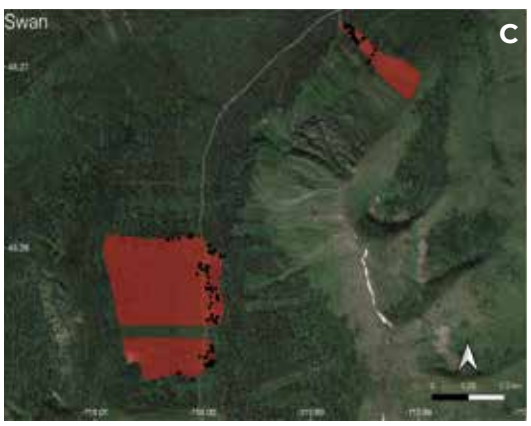


Figure 1: Study sites. The red rectangle in the state of Montana designates the general area of the four sampling sites. The sites are: (a) Red Meadow, Whitefish Range, (b) Going-to-the-Sun Road, central Glacier National Park , (c) Lost Johnny Creek, northern Swan Range , and (d) John F. Stevens Canyon, southern Glacier National Park. Black dots represent sample locations and red polygons symbolize avalanche paths. Satellite and map imagery: © Google[16] Maps produced using ggmap in R17.

For example, if we are interested in avalanche frequency relationships with regional climate patterns, and tree-ring samples are collected at an avalanche path scale, then a network of sampled paths need to be spaced and aggregated across the core of the climatically similar region. An example of how this is achieved is shown in Figure 1 for our data collection in Montana.

We targeted an even number of samples collected from trimlines on both sides of a particular avalanche path at varying elevations, as well as trees located in the lower track and runout zone of the selected avalanche paths (*e.g. Figure 2*). We collected samples from trees that were destroyed and transported, as well as those that remained in place. We used chainsaws and increment borers to collect three types of samples: cross sections from dead trees, cross sections from the dead leaders of avalanche-damaged but still living trees, and cores from living trees. We predominantly used cross-sections from trees in this study for a more robust analysis as events can potentially be missed or incorrectly identified in cores. We emphasized the selection of trees with obvious external scars and considered location, size, and potential age of tree samples.

After sanding the samples to a smooth surface, we analyzed each one in the laboratory using microscopes for signs of traumatic impact events likely caused by snow avalanches. We used a classification system from previous dendrogeomorphological studies to qualitatively rank the severity of the trauma and tree growth response from avalanche impacts using numerical scores ranked one (obvious avalanche signal) through five (weak signal)[6]. This classification scheme identified more prominent avalanche damage responses with higher quality scores and allowed us to remain consistent with previous work.

We used a multi-step process to reconstruct time series of avalanche activity at three different spatial scales: individual paths, sub-regions, and the entire region. This process incorporates the sample size, the number of growth disturbances, the number of trees alive in any given year, and the quality of the growth response to avalanches. We calculated the percentage of avalanche years captured in any one avalanche path compared to the avalanche years identified in the entire region. Finally, we used a variety of statistical techniques to look at relationships between long term climate and atmospheric variables. and identify trends in regional large magnitude avalanche activity over time.

RETURN PERIODS AND TRENDS IN AVALANCHE FREQUENCY

For our data from Montana, we analyzed 673 samples from 12 avalanche paths. We identified 30 years with large magnitude events across the region and a median return interval of about three years (from 1866–2017). Large magnitude avalanche return intervals and number of avalanche years vary throughout the smaller sub-regions, suggesting the importance of local terrain and weather factors. In our Montana dataset, the probability of avalanche detection of any given path is 40%, suggesting that if we sampled only this path, we would have only captured the regional avalanche activity 40% of the time. This clearly demonstrates that a single path cannot provide a reliable regional avalanche chronology. Specifically, our results emphasize the importance of 1) sampling more paths spread throughout the region of interest; 2) collecting a large number of cross-sections relative to cores; and 3) generating a large dataset that scales to the appropriate spatial extent.

Our statistical analyses suggest that specific seasonal climate and atmospheric circulation variables contribute to years with common avalanche events across the region. Maximum winter snow height (HS_{max}) and maximum winter snow water equivalent (SWE_{max}) exhibit negative trends throughout our period of record, with large magnitude avalanches occurring, on average, during years with greater HS_{max} and SWE_{max}. However, in recent decades, which are characterized by decreasing HS_{max} and SWE_{max}, we more frequently observed large magnitude avalanches associated with below average snowpacks. This suggests regional avalanche cycles can and do occur during years with below average snowpack. We know that snow structure is an important factor in avalanche release, and with a prerequisite weak layer in the snowpack, one loading event (i.e., a large storm) can initiate an avalanche. If that weak layer is deep in the snowpack, even a below average snowpack can produce a large magnitude regional avalanche event.

We also found a slight, but significant, decrease (~2% per decade, ~14% over the period of record) in the probability of large magnitude avalanche years from 1950-2017 in the U.S. northern Rockies region. Historically, large magnitude avalanche years in the region were characterized by stormy winters with above average snowpack. Over recent decades, avalanche years were increasingly influenced by warmer temperatures and a shallow snowpack, lowering the chances of a large avalanche. The decrease in HS_{max} and SWE_{max} through time corresponds directly to the estimated year-to-year and long-term decrease in avalanche probability. As continued climate warming drives further regional snowpack reductions, our results suggest that large avalanches associated with winters with large snowpacks may become less frequent.

Figure 2: An avalanche path west of the Continental Divide near Independence Pass, Colorado, with substantial forest damage from a widespread avalanche cycle in March 2019. E. PEITZSCH, USGS.

Though the probability of large magnitude avalanche years decreases through time as snowpack decreases, our results indicate large magnitude avalanches can occur during years of below average snowpack. This can partially be explained by warmer temperatures, a significant predictor of large magnitude avalanche years in our dataset, causing wet storms, or rain-on-snow events triggering large magnitude avalanches. In other words, though a decreasing probability of large magnitude avalanche years corresponds to snowpack decreases, warming temperatures can contribute to large magnitude avalanche years—at least over the near-term—through different mechanisms that are perhaps compensating for the effect of snowpack losses.

Lower elevation snowpacks are projected to be more susceptible to a warming climate and exhibit greater snowpack loss10–12, but higher elevations (i.e. above ~2,000 m) are projected to experience stable or increasing snowpack due to increased precipitation across the U.S. northern Rockies region[13]. Future precipitation projections and recent observations also indicate a smaller fraction of precipitation falling as snow, particularly at lower elevations[14,15]. These projections and observations align with our results in that a slight increase in precipitation translates to snow in many of the avalanche path starting zones but less snow throughout the track and runout zone. The increased surface roughness at lower elevations due to the presence of vegetation is likely to decrease avalanche runout distances. The potential effect this increased roughness has on large magnitude avalanche occurrence is that large avalanches may still initiate at upper elevations but may not be able to reach lower elevations due to lack of snow cover in the lower track and runout zones.

Our analysis shows an increase in March precipitation from about 1980 to 2017. The relationship of March precipitation with avalanche probability from 1980–2017 suggests that increasing spring precipitation in the region is also a partial driver of large magnitude avalanches during low snowpack years. The influence of spring precipitation on the probability of a large magnitude avalanche year during the latter part of our time series combined with warming temperatures provides further evidence for a potentially increasing influence of wet snow avalanches. This potential increase in wet snow avalanches may also partially explain and buffer further decreases in the probability of large magnitude avalanche years through time.

In summary, as continued climate warming drives further regional snowpack reductions in the U.S. northern Rocky Mountains, our results suggest that large avalanches during winters with large snowpacks will be less frequent, and that there exists a potential for more large avalanches when temperatures warm and spring precipitation increases. These results highlight how tree-ring records can provide data on the potential scale and spatial extent of avalanches as well as the influence of climate on large magnitude avalanche frequency.

WHAT'S NEXT?

It is important to note that the impact of a changing climate on avalanche frequency, character, and magnitude is likely to be different within any given region. The rate of change in avalanche behavior is also likely to vary. For example, a potential shift from dry snow avalanches to more frequent wet snow avalanches in the maritime climate of southeast Alaska may differ from any climate induced change in the continental avalanche climate regime in Colorado.

This is precisely the reason we are currently examining long-term relationships between climate and avalanches in multiple avalanche climates. We collected approximately 500 samples around southeast Alaska in avalanche paths that directly affect parts of downtown Juneau, as well as the primary electricity supply to the city. In addition, the dramatic landscape change to many parts of Colorado after the widespread avalanche cycle in March 2019 prompted us to begin a new study there. The Colorado Avalanche Information Center (CAIC) and U.S. Forest Service Rocky Mountain Research Station staff collected over 1,000 samples in over 15 avalanche paths thus far, with a goal of nearly 2,000 samples. This will allow us to compare long-term avalanche frequency patterns in different avalanche climates that can be used by forecasters and planners to guide decision-making on infrastructure planning, resource management, and public safety in the context of climate change.

Note: For those interested in the technical aspects of our research, we have recently published two scientific papers, "A regional spatiotemporal analysis of large magnitude snow avalanches using tree rings" in *Natural Hazards* and *Earth Systems Science* (https://nhess.copernicus.org/articles/21/533/2021/); and "Climate drivers of large magnitude snow avalanche years in the U.S. northern Rocky Mountains" in *Nature Scientific Reports* (www.nature.com/articles/s41598-021-89547-z).

DISCLAIMER

Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

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FORECASTING WET SLAB AVALANCHES

Start Zone Characteristics and Weather Variables

BY BRANDON LEVY, ANDREA TUPY, & RON SIMENHOIS

Forecasting wet slab avalanches (WSA) is notoriously challenging. One reason is the difficulty of determining where and how much free water is moving under the snow surface. Historically, WSA in Colorado most often occur in the late winter or spring when meltwater moves through the snowpack rather than due to a rain-on-snow event (Colorado Avalanche Information Center, 2022). Deciding when to warn for the onset of WSA activity is typically a difficult decision. In complex forecasting situations, we often rely on rules of thumb such as a growing concern for WSA activity after three consecutive nights when the air temperature stays above freezing.

From an operational forecasting perspective, rules of thumb may be useful, but they are hard to quantify and, in terms of WSA, don't tell us about the timing of the problem or where in the terrain WSA will likely occur. As highway avalanche forecasters we recognize that slope-scale characteristics in individual start zones are key to predicting the timing of WSA in any particular path. To improve our forecasts of wet slab avalanche activity, we designed a study to address the following questions:

- Are there specific start zone characteristics associated with WSA and do those influence the frequency and timing of WSA release?
- Is the rule of thumb that it takes three nights with above-freezing temperatures for WSA to occur a useful forecasting tool?
- Are there remotely-sensed weather variables that can help us more accurately forecast the timing and distribution of WSA release?

METHODS

We used the Colorado Avalanche Information Center's (CAIC) database of avalanche occurrence and remotely-sensed surface weather conditions. The CAIC keeps up-to-date records of all avalanches reported in the state of Colorado. This dataset is by no means a comprehensive list of every avalanche that occurs, but it does capture the general pattern of avalanches that happened in popular areas for backcountry recreation and in highway corridors. This dataset contains 823 WSA records over the last 10 years (2011 to 2021), which is large enough to use for simple statistical analysis as well as to make some generalizations about WSA occurrence in Colorado.

Images of WSA can provide valuable information about slope-scale characteristics of the terrain where these avalanches happen. Out of the 823 WSA records, about half (449 records) contain images of the avalanche start zones. We manually reviewed the images of these start zones and assigned them to one of five categories: cliffs/rocks, trees, couloirs within a rock/cliff band, slopes under a cornice, or open slopes (*Figure 1 and Figure 2*).

Figure 1: An example of a WSA start zone classified as cliffs/rocks. CAIC

Figure 2: An example of a WSA start zone we classified as an open slope. CAIC

When we classified all the start zones in our WSA images dataset we examined the start zone type, the trigger (natural or human-triggered), and their distribution; we also examined the timing of WSA associated with the different start zone types. WSA activity in Colorado often begins on southerly-facing slopes, and to reduce the noise in the elevation data, we used a subset of 186 avalanches (49% of the original dataset) that occurred on southerly-facing slopes in the above-treeline elevation band for our timing analysis.

To examine the rule of thumb that a pattern of two to three days and nights with air temperatures above freezing precedes WSA release, we used temperature data from the Swamp Angel weather station. For our radiation analysis we used data from the Senator Beck weather station. Both of these stations are operated by the Center for Snow and Avalanche Studies. They are in the CAIC's North San Juan forecast zone and in the US 550 highway corridor. The Swamp Angel station sits at approximately 11,000 feet and the Senator Beck station is higher at approximately 12,100 feet. We chose Swamp Angel with its near-treeline elevation for temperature data because Senator Beck is an alpine station and would typically be colder than many of the WSA start zones. We compared the temperature and radiation data against WSA avalanche events in that same forecast zone. We focused on the 2013, 2020, and 2021 seasons because each of these seasons had well-documented WSA cycles, each with over ten recorded WSA. In total, the database captures ninety-five WSA events in close proximity to these two stations during these three seasons.

Ultimately, we compared WSA activity to 72-hour temperatures, the 72-hour sum of net radiation, and the 72-hour sum of incoming radiation to see if there is any relationship between air temperature, net radiation, and incoming radiation with WSA release.

RESULTS

Almost 60% of the natural WSA occurred in start zones characterized as cliffs/rocks. Human-triggered activity far outweighed natural activity on open slopes. There were about the same amount of human-triggered WSA on open slopes as on slopes we classified as cliffs/rocks (*Figure 3*).

The timing of the natural WSA we examined (south-facing slopes above treeline) was statistically significant ($p < 0.05$) and occurred earlier in start zones with cliffs and rocks than on slopes without visible rocks or cliffs on the snow surface (*Figure 4*).

The temperature at the Swamp Angel weather station dropped below freezing in the 72-hour period prior to all of the 95 WSA in the three seasons we examined (*Figure 5*). This coincides with our personal experience where we have observed WSA release after a surficial freeze or even after a deeper overnight freeze.

We did not find a strong correlation between the 72-hour sum of net radiation and WSA occurrence (*Figure 6*). In the three seasons we examined, WSA occurrence was widely spaced across the three-day's net radiation sum between mid-winter and late spring. However, if we look at the correlation of the WSA occurrences and the 72-hour sum of incoming radiation (shortwave plus longwave) in the same period (*Figure 7*), we notice that all but one avalanche in the dataset occurred at values above approximately 35 kW/m^2. The occurrences are closely spaced in terms of the total incoming radiation values. This indicates that the 72-hour sum of incoming radiation value could be a useful tool to help forecast WSA. There are, however, more components to consider when forecasting WSA in order to possibly apply this threshold. For example, if the snowpack is already homogeneous and composed of melt-forms throughout, avalanche forecasters could observe a 72-hour sum of incoming radiation value above 35kW/m^2 without seeing WSA activity.

DISCUSSION

We chose to use 72-hours and 72-hour sums when we examined weather variables and WSA

occurrences because we wanted to test the three-day rule of thumb for temperatures above freezing and, more importantly, this timeframe would provide the minimum amount of data for operational planning. This is the case particularly for forecasting WSA activity in specific paths for highway forecasting. Operationally, a 72-hour sum allows for two days of available data and enables the forecaster to use forecast temperature and cloud cover (as a proxy for radiation) to predict conditions on the third day. A forecaster could assess after two days if the threshold is approaching and initiate proper action steps if it is determined the threshold could be reached on that third day. This would ideally inform decisions on mitigation or closure on the day before WSA activity. For example, if we were forecasting WSA for a highway path in Colorado and the 48-hour sum of incoming radiation was around 23 kW/m² and the next day was forecast to be warm and clear–meaning the third day could cross the threshold of 35 kW/m², the forecaster could make a decision with fair confidence to recommend mitigation or closure on that third day. This sequence would provide enough lead time to let the Department of Transportation and other stakeholders plan and provide notification to the traveling public, etc.

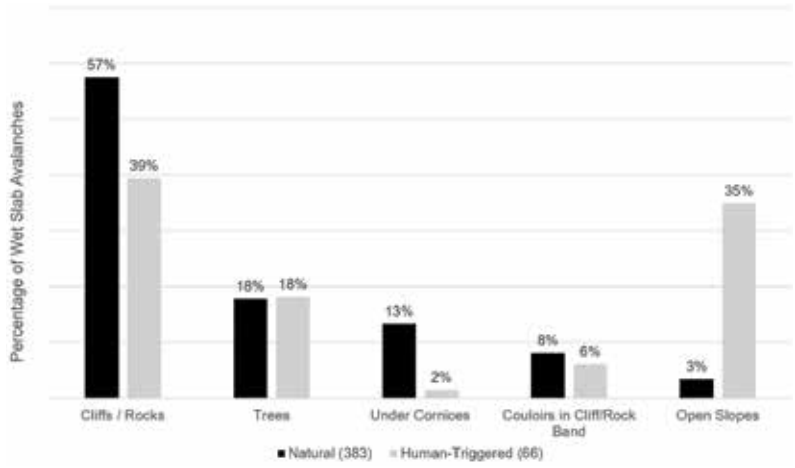

Figure 3: Distribution of WSA based on start zone type and trigger illustrates that nearly 60% of the natural WSA in our dataset occurred in start zones defined by cliffs or rocks.

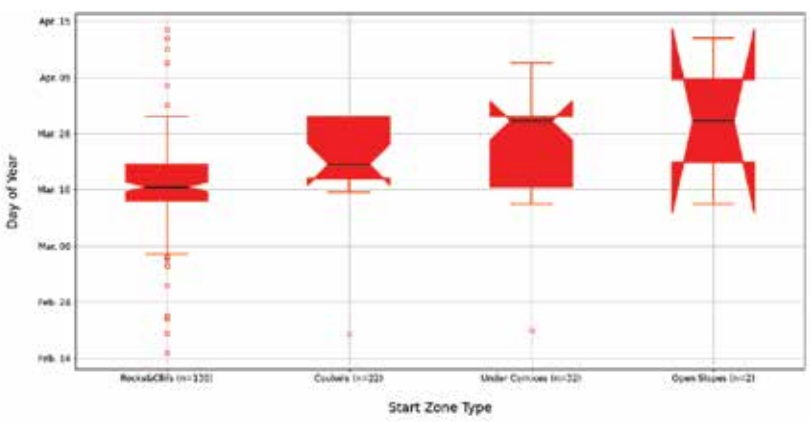

Figure 4: WSA time of year release distribution for the different start zone types (n=186). In our data, WSA with start zones with rocks and cliffs released, on average, more than ten days before WSA under cornices. The black lines denote the mean, the red boxes are the center 50% of the data (interquartile range) and the "wedges" in the sides of the boxes are the 95% confidence interval. When the wedges of two groups don't overlap, the difference between those groups is statistically significant (P-value < 0.05). The dots are outliers.

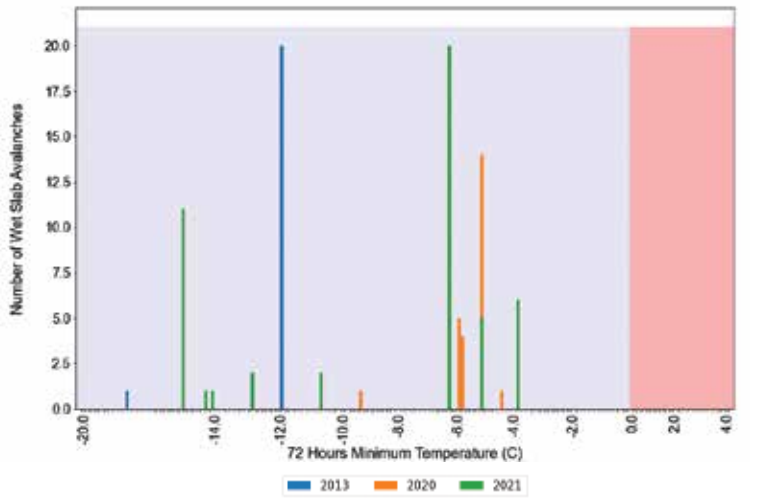

Figure 5: WSA occurrence and 72-hours minimum temperature (Celsius). The three years we examined are represented as blue (2013), orange (2020), and green (2021) in the bar graphs. The x-axis is the minimum temperature over three days at the Swamp Angel weather station. The light red background indicates temperature values above freezing whereas the light blue background indicates values below freezing. Not one of the avalanches that we examined occurred after a 72-hour period of above freezing temperatures.

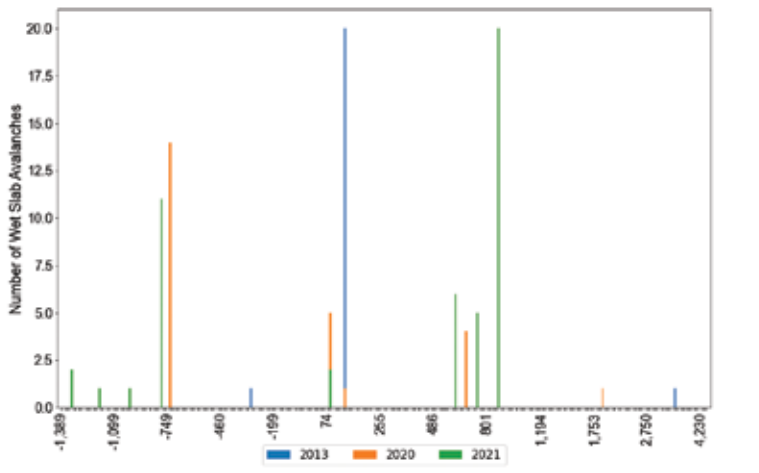

Figure 6: 72-hour sums of net radiation with the 95 natural WSA on the y-axis and the radiation value (W/m²) on the x-axis. As a point of reference from 7pm on March 30 to 7pm on March 31 in 2021 the one day net radiation value is -734 W/m². The WSA occurrences are scattered throughout the plot; this indicates that the 72-hour sum of net radiation is not a useful indicator for WSA release.

For our radiation analysis it is valuable to have some reference information because many weather stations do not have radiation instrumentation and radiation values are not always very intuitive. Incoming solar radiation on a sunny, clear day can vary dramatically depending on the time of year and the latitude. For example, the data from Senator Beck shows that the total incoming daily solar radiation in April is over 160% of a typical value measured on a sunny day in January. The daily mid-March total incoming solar radiation on a clear, sunny day in the Northern San Juan mountains is slightly above 13 kW/m², and less than 9.5 kW/m² on cloudy days.

Seventy-two hours above freezing was not a required weather variable for natural WSA release for the 95 WSA we examined. Given the limited dataset, we can't say that the "three-days above freezing" rule of thumb is not useful or valid. However, we recommend that avalanche forecasting programs evaluate it in their area(s) for their specific start zone and weather station setups before relying on this rule of thumb.

Total incoming radiation (shortwave plus longwave) may be an effective tool for operational forecasting for WSA in Colorado. This finding makes intuitive sense. Instead of thinking about snow and its ability to cool due to radiative loss, we can shift our focus to where most WSA occur: amongst rocks and cliffs. These characteristics of the start zones are likely absorbing the incoming radiation and transferring energy as heat into the adjacent snowpack.

Forecasting WSA is indeed a complex puzzle and we don't provide a simple or complete solution. For example, in our 72-hour incoming solar

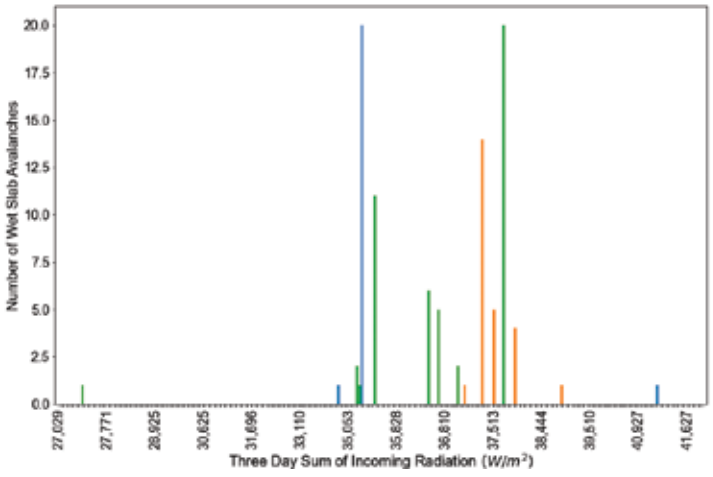

Figure 7: 72-hour sums of incoming radiation (W/m²) and natural WSA (n=95) on the y-axis. As a point of reference from 7pm on March 30 to 7pm on March 31 in 2021 the one day incoming radiation value is 11.4 kW/m². In this plot the WSA occurrences are closely spaced and almost all occur with a 72-hour sum of incoming radiation value above 35 kW/m².

radiation data we noticed an anomalous data point which when we expanded to observations without photos there were 13 WSA in a single day where the 72-hour sum of incoming radiation was well below our general guideline of 35 kW/m² (*Figure 7*). A forecaster using the 72-hour sum of incoming radiation threshold alone may have been surprised by that WSA activity. Uncertainty and limitations aside, we believe there are some useful ideas here that can help avalanche professionals forecast WSA.

CONCLUSION

Seventy two-hours of above-freezing temperatures does not appear to be a necessary component for WSA release in our dataset. Our findings suggest that, for a 72-hour timeframe, incoming radiation is a stronger predictor of WSA occurrence than net radiation. This result makes intuitive sense when considering where WSA most often occur. The majority of the natural WSA in our dataset released from start zones with cliffs and rocks and very few natural WSA released on open slopes. The cliffs and rocks in the WSA start zones absorb the incoming solar radiation whereas open slopes experience more radiative energy loss— and significantly less natural WSA activity. Additionally, we found that on above treeline south-facing slopes, there is a temporal progression of natural WSA activity associated with the start zone characteristics. Our analysis indicates a progression of WSA activity that begins earliest from start zones with cliffs and rocks and eventually progresses to slopes without rocks above the snow surface.

LW: You do not directly address the issue of structure of the snowpack, specifically situations with and without what Reardon and Lundy called the "funny business." Any assumptions here, such as "all slopes in Colorado have some kind of basal facets?" Or is this something you chose not to address?

BL: We did not look at snowpack structure. While we know that plays a key role our only allusion to the structure is acknowledgment that there will be days where the three-day sum of incoming radiation is above 35kW/m² without WSA. One possible next step for our work will be to incorporate structure, sz characteristics, and incoming radiation and analyze their collective impacts on WSA occurrence.

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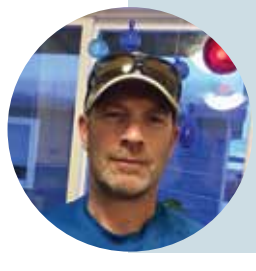

RON SIMENHOIS is an avalanche forecaster with the Colorado Avalanche Information Center. Ron enjoys most things snow most of the time. He had fun thinking about wet slab avalanches with Andrea and Brandon, and he is proud to call them colleagues and friends.

DESTRUCTIVE AVALANCHE CYCLES IN COLORADO AND A LINK TO ATMOSPHERIC Rivers

BY JASON KONIGSBERG, JONATHAN RUTZ, SPENCER LOGAN, & ETHAN GREENE

INTRODUCTION

In March of 2019 a massive avalanche cycle shut down interstate commerce and travel across Colorado for an extended period. Avalanches damaged or destroyed cabins, houses, a natural gas pipeline, a high-voltage transmission line, a 130-year-old kiln, and acres of forest. Although it was clear from discussions with longtime avalanche professionals that we were witnessing a rare event, we didn't know how rare. A series of atmospheric rivers (ARs) contributed to this event and we wondered if similar weather events were associated with other large avalanche cycles. We set out to collect information on other large avalanche cycles in Colorado and the weather events associated with them.

Some previous studies have looked at avalanches and AR events across the western United States. Birkeland and Mock (2001) identified significant moisture transport from the Pacific as a key factor in a major Western US avalanche cycle in 1986, but at the time, research into AR events was in its infancy. Hatchett et al. (2017) found that the ratio of avalanche fatalities to AR events is greatest in interior states like Colorado compared to coastal states where AR events are more frequent. Although avalanche fatalities are tragic events, individual avalanche accidents may not have widespread impacts to interstate commerce and travel. Primomo (2016) used integrated water vapor transport values to determine that AR events played a significant role in all very large (D4) avalanches in a specific avalanche path in Utah. We built off methods used by Primomo and Hatchett et al. to answer our questions about the influence of ARs on widespread destructive avalanche cycles in Colorado.

METHODS

There is not a single list of large avalanche cycles in Colorado or criteria for an impactful avalanche event. We looked through the Westwide Weather and Avalanche dataset. We looked through the data collected by the Colorado Avalanche Information Center, including written narratives, storm reports, publications, and annual reports. We reached out to people that did a variety of work with avalanches in the 1980s and 1990s, and interviewed them about events they experienced. This produced a list of notable avalanche cycles between 1950 and 2021. Eight of these cycles had a significant impact on people in Colorado, closing roads for extended periods of time and damaging buildings and infrastructure, over a broad area in Colorado (*Table 1*).

Next we reviewed the synoptic weather patterns for each of these eight events. We used the 500 mb geopotential height anomaly from the National Center for Environment Prediction (NCEP) North American Regional Reanalysis (NARR) to identify patterns in the position of pressure ridges and troughs over North America.

START DATE	END DATE	REGION AFFECTED	SIGNIFICANT EVENTS
2/13/1986	2/24/1986	Northern and Central	An avalanche in the Little Professor ran across US6 and into the Arapahoe Basin ski area's parking lot. The debris crossed the parking lot and damaged the Molly Hogan lift. Mine buildings damaged at Coal Basin Mine (near Redstone), Henderson Mine (Berthoud Pass), and Madonna Mine (Monarch Pass). Avalanches out of several paths reached I-70 in Summit and Clear Creek counties for the first time since the Interstate was built.
2/18/1993	2/25/1993	All	Avalanche on Vail Pass impacted 10 vehicles. House and a yurt were damaged in Castle Creek (near Aspen). Mine building damaged near Silverton. Avalanches covered 4 continuous miles of US-550 near Silverton. Red Mountain Pass was closed for 17 days and Coal Bank and Molas Passes were closed for 7 days, isolating the town of Silverton. Major avalanche cycle recorded near Gothic.
2/11/1995	2/15/1995	All	The Big Marvin slide path near Vail reached I-70 for the first time. Cabin near Gothic from 1890 destroyed in an avalanche. Two condominiums hit and damaged near Crested Butte. Structures damaged at Maroon Lake campground near Aspen. Two boxcars knocked 100 feet off track near Tennessee Pass. 2500 square foot home near Aspen destroyed.
1/29/1996	2/3/1996	Northern and Central	Power lines destroyed in Conundrum Creek near Aspen. Grizzly slide near Loveland Pass reached US-6 for the first time since the 1960s. At Loveland Basin a ski area bus, loader, grader, snowmobile and 3 cars caught and damaged or destroyed.
3/17/2003	3/21/2003	Northern	Avalanche created new path above Silver Plume and put a large amount of snow and trees on the frontage road, dammed up Clear Creek and put trees and debris on I-70. Numerous other structures were hit and damaged from Rocky Mountain National Park to Silver Plume to Mt Evans highway.
1/8/2005	1/13/2005	Central and Southern	Battleship path hit US-550. Red Mountain Pass closed for 7 days. Communications building destroyed on Coal Bank Pass, power lines and out building destroyed by Ophir. Cabin and other structure destroyed near Marble
1/8/2017	1/13/2017	Northern and Central	House destroyed in Maid of Orleans path in Peru Creek near Keystone. Numerous natural avalanches impact I-70.
3/4/2019	3/15/2019	All	Numerous structures damaged or destroyed, infrastructure damaged, and acres of forest destroyed in an avalanche cycle that impacted areas between Wolf Creek Pass and Berthoud Pass. This avalanche cycle included the largest number of size D4 and D5 avalanches over the largest part of Colorado of any cycle on record or recalled by the people we interviewed.

Table 1: A list of eight of the most significant avalanche cycles since 1983 with notable events. The region impacted column identifies which of Colorado's three mountain regions were most affected.

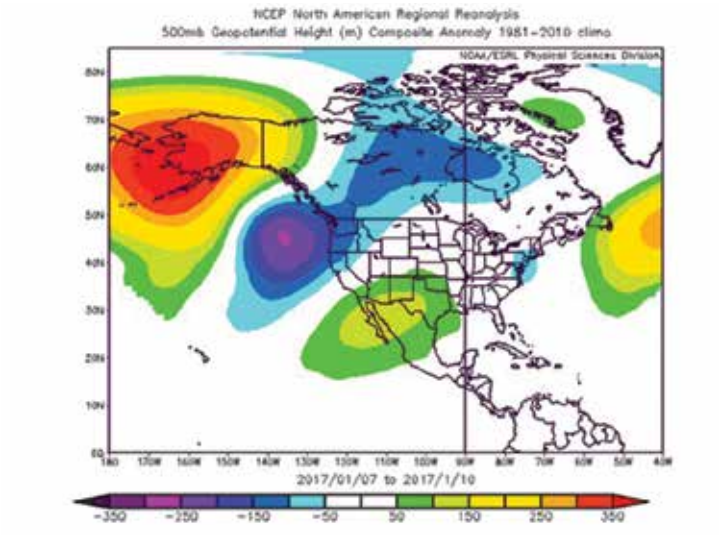

Figure 1: The 500 mb composite anomaly for January 2017. This synoptic pattern with high-pressure anomalies over Alaska and Northern Mexico and a low-pressure anomaly of the northwest coast of the US was present in seven of the eight destructive avalanche cycles.

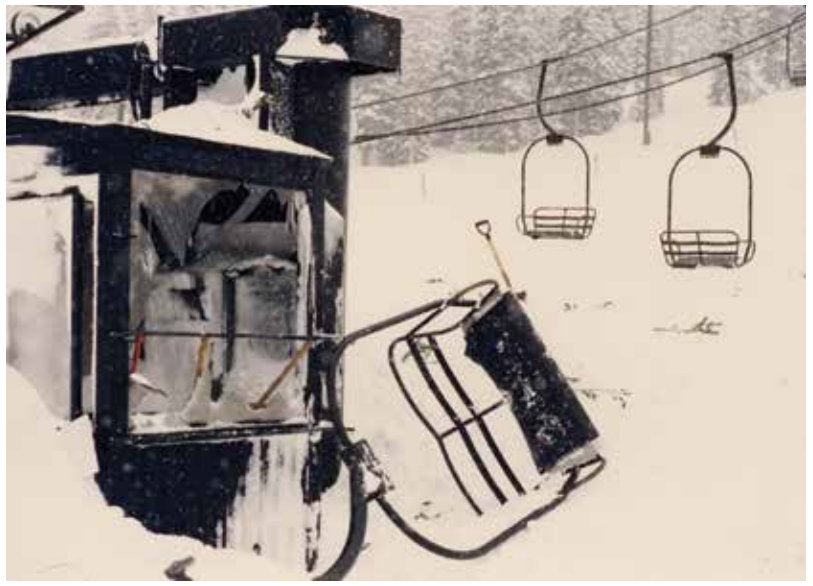

Figure 2: A photo of the damaged Molly Hogan lift at Arapahoe Basin from an avalanche out of the Little Professor slide path near Loveland Pass in February of 1986. The avalanche crossed the highway and the parking lot before striking the lift.

To understand if an AR impacted Colorado during each of these avalanche cycles, we looked for the presence of strong integrated vapor transport (IVT) at three locations in Colorado in the days leading up to the onset of avalanche activity. The presence of strong IVT is the primary indicator of an AR penetrating inland across the interior West (Rutz et al, 2014). IVT is commonly used to evaluate the strength and boundaries of an atmospheric river. Other parameters such as integrated water vapor (IWV) can be used in coastal environments (Guan, 2015), but IWV does not show the inland penetration of ARs as it does not include the transport of water vapor (Naya et al, 2014) We used an IVT dataset from a catalog developed by Jonathan Rutz of the National Weather Service. The IVT dataset begins in 1980. We calculated percentile ranks for the average one-day IVT for the period of record from November 1 through April 30 for three SNOTEL sites representative of the three mountain regions in Colorado: Grizzly Peak in the Northern Mountains, Schofield Pass in the Central Mountains, and Red Mountain Pass in the Southern Mountains (Table 2). This allowed us to compare IVT values in Colorado to Colorado, not AR thresholds developed for coastal regions.

Lastly we wanted to look at accumulated snowfall around the period of these eight avalanche cycles. We employed a similar percentile rank method for the seven-day change in snow water equivalent (SWE). We used the maximum seven-day delta value from the date range for each cycle. The values were from the three SNOTEL sites from which the IVT values were derived.

RESULTS

We found a common synoptic scale pattern in seven of the eight cycles (*Figure 1*): larger than normal height of the 500 mb surface over Alaska (ridge), and lower than normal height of the 500 mb surface over the Pacific Northwest (trough). This particular upper-level pattern allows atmospheric rivers (ARs) laden with subtropical Pacific moisture to not only make landfall along the US West Coast, but also to penetrate inland through a pathway south of the Sierra Nevada, reaching Colorado relatively unimpeded by terrain barriers (Rutz et al. 2014).

During each of the eight avalanche cycles, we found that maximum one-day average IVT values at the three Snotel sites ranked in the 95th percentile of all one-day average IVT values for the period of record (1980 to 2019). The March 2003 avalanche cycle showed high IVT values, but the moisture stream originated from the Gulf of Mexico, an atmospheric river event but very different from the events that initiate over the eastern Pacific and penetrate from the West Coast inland.

Our findings also show that for each destructive avalanche cycle the seven-day change in SWE ranked in the 95th percentile for the SNOTEL period of record (*Table 2*).

DISCUSSION

Regardless of the weather pattern leading to heavy snowfall, heavy snow and loading is only one contributing factor to a destructive avalanche cycle. This research does not explore one other key component to destructive avalanche cycles, which of course is the snowpack. Even though we did not look at snowpack stratigraphy, we did look at the timing of these destructive avalanche cycles and noticed that no destructive avalanche cycle on our list occurred before December 26 or after about March 17. Three of the eight destructive avalanche cycles occurred in mid-February, within four days of Valentine's Day. Avalanche

APPROXIMATE CYCLE START DATE	REGION	MAX 7-DAY DELTA SWE	7-DAY SWE PERCENTILE	MAX 1-DAY AVERAGE IVT	1-DAY IVT PERCENTILE
2/13/1986	North	5.3	99	204	99
	Central	12.6	Record	182	99
2/18/1993	North	3.4	99	117	95
	Central	8	99	109	95
	South	4.8	99	121	95
2/11/1995	North	4.1	99	115	95
	Central	10.4	99	128	95
	South	3.7	95	129	95
1/29/96	North	4.4	99	142	95
	Central	5.4	95	126	95
3/17/03	North	5.1	99	114	95
1/8/05	Central	10.3	99	143	99
	South	4.1	99	160	99
1/8/17	North	5	99	266	99
	Central	9.5	99	253	99
3/4/19	North	4.4	99	175	99
	Central	9.9	99	182	99
	South	5	99	181	99

Table 2: The maximum 7-day change in SWE values and 1-day maximum average IVT at select SNOTEL sites. We compared both 1-day average IVT and 7-day SWE changes during the cycles to the period of record for the site. The percentile ranks are color-coded as black for the maximum rank, red for 99th percentile or higher, and orange for 95th to 98th percentile.

professionals in Colorado have long considered mid-February as a particularly dangerous period, with clusters of human-involved avalanche accidents (Logan 2021). By mid-February significant volumes of snow have built up in avalanche start zones and the often-present layer of basal depth hoar has gained enough strength to support an overlying slab. Large storms in February can increase the snowpack volume over deeply buried weak layers to the point where it fails catastrophically.

It is important to note that high IVT values can occur without a corresponding avalanche cycle. We looked at other high IVT value days and found no corresponding avalanche cycle. AR events are most likely to make landfall on the Western US coast in autumn. They decrease in frequency throughout winter. Although Colorado is impacted by more ARs early in the season, the snowpack then usually does not have enough volume to produce destructive avalanches.

While researching snowfall amounts with each avalanche cycle, it was interesting to see that almost all of the destructive cycles can be associated with near-record storm events. It seems somewhat obvious that this would be the case, but with Colorado's continental snowpack, we sometimes see very large avalanches release with small, incremental loads. Although we have seen a series of small snowfall events produce very large avalanches, that avalanche activity is typically isolated. All of the avalanche cycles we documented as part of this study were triggered by big storms and multi-day precipitation events.

CONCLUSIONS

A similar synoptic weather pattern is shown in 7 out of 8 destructive avalanche cycles in Colorado since 1983. This weather pattern is linked to an influx of moisture related to atmospheric rivers and heavy snowfall. Only recently have we been able to access forecast tools that show us predicted IVT values. Identifying a synoptic pattern of high pressure over Alaska over top of low pressure near the Pacific Northwest can clue us in to begin looking at IVT values and the potential for an atmospheric river. These long streams of moisture are visible on satellite imagery well before they make landfall. Knowing that this weather phenomenon is a contributing factor may help avalanche forecasters predict destructive avalanche cycles with a longer lead time.

Identifying a synoptic pattern of high pressure over Alaska over top of low pressure near the Pacific Northwest can clue us in to begin looking at IVT values and the potential for an atmospheric river.

ACKNOWLEDGMENTS

We would like to thank Knox Williams and Art Judson for their work on the Westwide Weather and Avalanche Network. The data they collected was a key component to organizing the destructive avalanche cycle list. Brian Lazar, Mike Cooperstein and other CAIC staff spent countless hours merging avalanche data from numerous sources into a usable database. Betsy Armstrong, Richard Armstrong, Dale Atkins, Don Bachman, billy barr, Denny Hogan, Susan Hale, Nick Logan, Art Mears, Mark Mueller, Ray Mumford, Jerry Roberts, Craig Sterbenz, and Scott Toepfer participated in our interviews and their knowledge and insight was extremely helpful. ⬢

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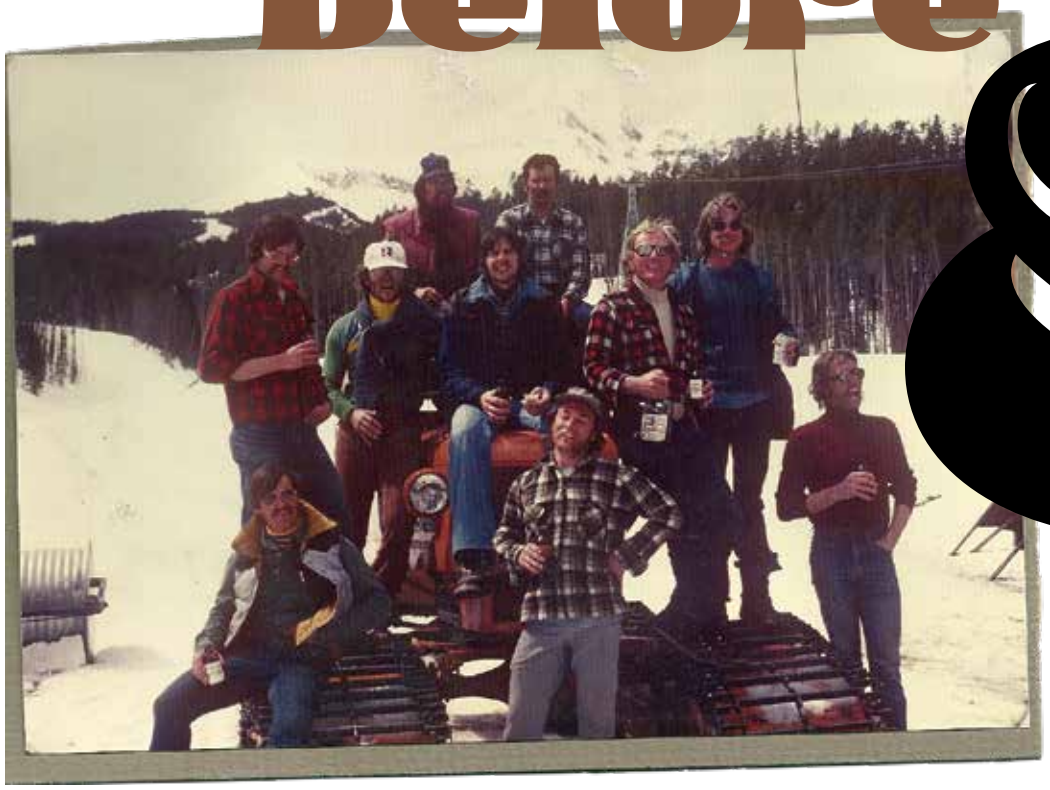
Before

Skiing was common for kids growing up in Bozeman, Montana, in the 1960s. I took up the sport when I was in eighth grade, older than most kids; I bought my first set of equipment, lace-up boots, wooden skis, and a 25-dollar season's pass at Bridger Bowl all for a little over 100 bucks using money I made from my paper route.



I found skiing to have a steep learning curve, but after the first few years I got the hang of it and figured that the best way to support my new habit was to join the National Ski Patrol's Junior program. The Junior Patrol adult advisors were Beep Dixon and Mark Lakey. Beep became a professional patroller at Bridger Bowl and later transferred to Big Sky's pro patrol the first year of Big Sky's operation.

The Bridger Bowl Ski patrol had a wild west personality despite the gentlemanly and competent leadership of Duain Bowles. Duain, no matter how he might have tried, could not dampen the occasional delinquency of the group. The last straw came at a season's end ski patrol party in the Bridger Bowl lodge. The party was getting wild and the general manager, Emile Cochand, was walking up the stairs to break up the affair at the precise moment when the large size Beep decided to put on his skis and ski down the stairs, where he collided with the smaller Emile, pasting him against the wall where the stairs made a sharp right-hand turn. Emile then fired the entire Bridger ski patrol without negotiation. The next year was the first year of Big Sky's ski season and the new ski patrol director, the well-known Montana mountain climbing guru Jim Kanzler, had a good pick of experienced former Bridger Bowl patrollers to staff Big Sky's first professional ski patrol.

These first patrollers included: Director Kanzler, assistant patrol director Todd Pitcher, Terry Onslow, Beep Dixon, Mike Donovan, Brian Leo, Dave Klatt, James Garrett, Steve Dubay, and Brent (Tony) Perkins as best as I can remember. I joined the group the second year of Big Sky's ski operation along with Tom Bowles. Tom was Duain's youngest son who had just graduated from high school and was a fellow member of Bridger Bowl's junior ski patrol. We became roommates in the employee dormitory. Father Duain was a renaissance man who had many skills, one of which was designing automated irrigation systems for industrial farming in Eastern Washington. Thus, when Tom left the nest the first time to join the Big Sky ski patrol, Duain gifted him a 50 lb. sack of beans, and Tom's mother Elie added a crock pot. Each week we only had to stop by a store to pick up a fresh package of ham hocks to load up the crock pot so that we always had a hot meal after a hard day of ski patrol work, usually with a stop at the bar in between. Luckily, our dorm room had windows that opened to the outside.

SKI PATROL LIFE

To say ski patrolling at Big Sky the first few years was a learn-as-you-go challenge is an understatement. Based on his mountaineering, skiing, and leadership skills, I cannot imagine a better director and leader than Jim Kanzler. The most obvious problem under Kanzler's direction was the massive amount of avalanche terrain hanging above the ski runs. Ski patrollers "taking rides" was not uncommon. I could not believe it when I was first set out on an avalanche control route on the high traverse above the Lone Peak bowl. Two or three patrollers would take turns breaking trail from the top of the Triple Chair (now Powder Seeker) out across the bottom of the gullies all the way over to near the top of the gondola, stopping at points of perceived safety with landmarks such as Black Rock to throw hand charges in the direction of travel to bomb one's way to the end of the cirque. There were many pockets of wind slabs that had to be crossed below an enormous area with megatons of potentially unstable snow and fragile cornices hanging above your head.

▲ ABOVE: Patrol end of season circa 79, Stutzman second from right.

▲ Big Sky ski patrol year (~1977 or 78?). L to R: Tom Boles, not sure, Dave Klatt (aka Gramps), Terry Onslow, James Garrett, Jim Kanzler, maybe Tod Pitcher, maybe Mike Donovan, not sure on the end.

▲ Alta ski patrol year (1974–75). Big Sky connection: Back row second from left, Dave Hamre, third from left Hambone, sixth from left Dougal McCarty, next to Onno Wieringa, eventual Alta GM.

BY DOUGLAS (DOUGAL) MCCARTY

After

Big Sky and the Big Sky Ski Patrol

▲ End of season ~1977. Mark Kalatowski (Doby) middle row second from right. Tom Bowles back row left. Terry Onslow front row right.

▲ Jim Kanzler

▲ Avalanche control explosive cache: 'Keep Away', James Garrett writing down records.

▲ Lynn Broughton

▲ Bill Dallas (left) and Don Mitchel (right), the Bridger Bowl snow ranger.

▲ Brian Leo

◀ Bill Dallas (L) and Terry Onlslow (R) at Bridger Bowl in the early days, off to control work.

On one such high-traverse day, three of us started out from the top of the Triple Chair with Brent Perkins in the middle; I was the last in the line. Early in the traverse, we were crossing above a snowless low-angled talus cliff when the slope we were on started to move. The lead patroller, I do not remember who, quickly skied out of the moving slab in the direction he was facing. At the same time, I did what amounted to a flying kick turn and did the same thing, escaping the way I had just come. Brent was in the middle of the several hundred-foot-wide slab and was swept over the talus cliff.

The other two of us hurried around to the base of the cliff to find Brent sitting on top of a significant pile of debris. He was as white as a ghost and looked like he had been through a cheese grater. I will never forget his skis; they were orange Atomics, one of which was completely delaminated from

tip to tail. We picked up all his pieces and helped the much-shaken Brent down to the patrol room.

Frequent rides like this somehow did not result in disaster. I remember once clearing the steep terrain of the Little Rock Tongue (LRT) after a long hard trail-breaking traverse, only to get caught doing a ski check. As I started to accelerate through sparse timber, I glanced up to see a horizontal tree limb that I was about to go under, I shot my arms up just in time catch the limb and barely hung on as the snow continued sliding down around my legs, pulling hard on my skis. I almost lost my grip, which could have ended badly.

STEEP SKIING

The Big One. The conical shape of Lone Mountain, with its steep smooth, treeless slopes and solitary position between the Spanish Peaks to the north and the Hilgards to the south beckons to be skied. The symmetrical shape of the Lone Mountain is unique. The southeast through southwest sides are smooth, steep, and open mountainsides from summit to valley; any skier looking at the peak would think or exclaim, " I want to ski that! "

Early in the winter of Big Sky's second year, James Garrett, Brian Leo, Dave Klatt, and I climbed up to near the summit and looked down the longest unbroken concave slope I had ever seen, immediately south of the long east ridge that defined the bowl of the ski area. The day was windless, cold, and clear, with two feet of light powder snow uniformly distributed over the whole mountain. Somehow the weather history did not produce any avalanche-related discontinuities and we all were able to ski the wide-open, knee-deep line from top to bottom until our legs begged us to stop and look back with big smiles at our sets of parallel tracks.

Before joining the Big Sky ski patrol, James was a government major at Montana State University, and he was fascinated by the philosophies of Karl Marx and Vladimir Lenin. The names of the two prominent wide concave faces on Lone Mountain's south side were thus christened Lenin and Marx, and the names stuck, surprisingly to this day. The previous year, Garrett had a significantly different Lone Peak experience and first ski descent.

While Lone Mountain stands alone like a giant traffic cone when viewed from the east, its symmetry is interrupted by a proportionally smaller 'scoop' forming a shaded cirque on the northeast aspect that was created by Pleistocene glaciation. The cirque is flanked by the dramatic west facing wall on the right-hand side when looking up. To the left of the West Wall are two spectacular steep couloirs that wind their way down from just below the summit. The larger of the two, called now The Big Couloir, starts close to the summit; it is steep and wide with a couple of dogleg turns before emptying out in the bowl above the Powder Seeker lift. The Little Couloir starts lower and is bound on the looker's right side by the abrupt edge of the West Wall. This feature is shorter but much steeper and less well defined than the Big Couloir neighbor.

The Big Couloir is the obvious line above the cirque that calls out to be skied. Access to Lone Mountains operations during the first (and subsequent) years of Big Sky's existence was controlled by the ski patrol to ensure the safety of people wanting to climb up and ski down, and to protect paying customers, where the possibility of a skier-triggered avalanche is a significant risk to those below.

The Big Couloir was on many people's minds that first season when Kanzler directed James Garrett and Brian Leo to hike up to the summit, carrying hand charge explosives for avalanche control, along with an awkward hand auger to bore holes in the massive snow cornice that barred entry into the couloir. The plan was to drop hand charges into the boreholes to blast off the cornice before it would grow, weaken, and collapse on its own at an inappropriate time.

The day was crisp, cold, and clear, and many ski area employees and customers gathered near the top of the Triple Chair to watch their progress, while management watched through a spotting scope near the base area. Occasional explosions from hand charges broke the winter silence as the two patrollers worked their way up the ridge and slowly made their way to the summit. At the top of the couloir Brian Leo, an accomplished climber and frequent climbing partner with Kanzler, put the less experienced (at the time) Garrett on belay

▲ Big Sky ski patrol ~1977 or 78?
L to R: Dave Stutzman, Brian Leo, ???

▲ Big Sky ski patrol year #2. James Garrett and Dave Klatt (in front) hiking up the ridge above Triple Chair to ski the south face, perhaps the first ski of Marx. DOUGAL MCCARTY

▲ Stu cutting a cornice.

with a climbing rope while James walked out on the overhanging cornice with the auger and started drilling the first hole to fill with a hand charge.

James had not yet finished this first hole when many tons of hard wind-packed cornice snow collapsed below his feet, sending a torrent of blocks the size of refrigerators down the Big Couloir while James, auger in one hand, dangled off the now-vertical snow cliff. The collapse and James's weight pulled Brian hard into the snow on the backside as he dug in his heels. Brian gripped tight on the rope which he had only set up as a hip belay. This incident caused all the spectator's jaws to drop, including the area manager who was watching James dangle through the spotting scope. The boss promptly called Brian on his radio to demand to know what the hell was going on up there. Brian's reply was equally prompt and to the point; "I'll have to call you back, I'm kind of busy now," as he held onto James who was thrashing and kicking at the end of the rope.

James somehow held onto the auger and with Brian's help they managed to get everything up off the precipice and onto the backside of the ridge. The two patrollers put themselves all back together, unscrewed the auger, and stowed it in a backpack. After they called on the radio that all was well, Brian said to James that he thought they earned their reward for the day's work, and they entered the couloir from the side, skiing down the beautiful line where they were met with cheers from the crowd gathered at the Triple Chair, celebrating the first documented descent of the Big Couloir.

The Little One. In Big Sky's second year the local folks often made the hike to Lone Peak's summit to ski down the Big Couloir. There were occasional mishaps. I remember watching one of the local restaurant worker fellows fall in the upper section and take off like rocket, ricocheting off the rock walls where the couloir turned before stopping in softer snow on the apron at the bottom of the chute. With some help he was able to make his way down under his own power, but it easily could have been worse.

▲ Lone Mountain south face, year #2 knee deep powder. 📷 DOUGAL MCCARTY

▼ Terry Onlslow saluting director Kanzler.

▶ Treatment room after a long night.

Despite these occasional mishaps, skiing the Big Couloir was relatively common and was sought after by many locals and employees. A few people started to eye the steeper Little Couloir neighbor with skiing intent. Mark Kalatowski, an accomplished ski racer and local coach and later Big Sky ski patroller, was one of them. The Little Couloir was much steeper and less well defined. The top half was more like a steep, broad, often rocky face, topped by a corniced rim from the edge of the West Wall to the buttress that forms the boundary of the Big Couloir. This fluted face funnels into a more defined chute and then turns to the looker's right and empties into the bowl near the bottom of the West Wall.

While the Big Couloir usually fills with skiable snow early in the season, it was obvious that the Little Couloir did not often have skiable conditions. If it were ever skiable, it would be late in the winter or in the spring when there was a maximum snowpack, but needing a recent snowfall well-adhered to the mountain, as it turns out. One such late winter day Mark Kalatowski invited me to hike up the peak to perhaps have a look at the Little Couloir.

The day was warm, clear, and calm. The most recent snowfall had been days before and the temperatures had been ideal to bond the newest fallen snow to the underlying surface. With a light lunch in our pockets, we threw our skis over our

▼ Early morning shoot.

View from the top with the Dirty Sox club: Jim (Jimbo) Humphries, Douglas (Dougal) McCarty, Jim Emerson, and Brian Leo.

shoulders and started up the familiar ridge above the Triple Chair. We took a break on the summit to enjoy the day, with the Tetons visible on the southern horizon.

With little discussion we skied down the northern ridge past the Big Couloir and along the rim of the broad beginning of the Little Couloir and stopped at its far end, at a point just before the topmost ridgeline of the West Wall. Here we had the best view of the fluted upper part of the Little Couloir with its corniced rim. Skiing anywhere in this central region looked impossible. However, just where we had stopped, there was a feature right below us, a narrow chute just on the edge of the West Wall hidden in view from most angles. The chute was barely wider than a pair of our 210 cm skis, and looked skiable, despite it being much steeper than anything either of us had skied before. The chute angled toward the center of the funnel where it merged with the main feature, opening into a clear path to the bowl below. We sat down comfortably in the snow, scratched our heads, and snacked while we thought about things. For dessert, we shared an apple, and after the last bite, threw the core down the narrow chute, stood up and with few words started down.

I went first. The skiing was different and more difficult than anything I had done before, but there was just enough softer snow on the surface that the skis could sink in almost to their width, so we were not hanging on a rock-hard substrate by our ski edges. I had to use all the strength in my legs to make 180-degree jump turns, landing with my uphill elbow almost touching the slope above. With plenty of adrenaline moving in my veins I would take a deep breath and repeat the process. Linking three such windshield wiper turns in a row was the most I could make. Then I would stop with bent knees, arms out for balance, catching my breath before repeating the sequence. After a couple of these tenuous sequences Mark started to follow, using the same technique. Near the bottom of the steep part, the chute was bordered on the left by a cliff with no natural guardrail. A fall in this part of the descent would send the skier over the cliff perhaps 100 feet before hitting a rocky slope below. We both made a conscious decision to be extra careful skiing past this exposed section where the line turned to the left into the main part of the Little Couloir system. Here the angle lessened, and we got our fun reward turns into the bowl below, down to the top of the Triple Chair. Sometimes things just work out. We christened the line Apple Core Couloir for the real apple core that we followed down the chute.

THE STEPPINGSTONE

After my first year of patrolling at Big Sky, I felt that I had a marketable skill despite some doubts in the back of my mind that ski patrolling was sustainable for me in the long run. However, this unconscious thought was not strong enough yet to change careers. Like the old cowboys, I was ready to move on to a new "range" and so I joined the Alta ski patrol in Utah for the next ski season. Here I met some likeminded souls and became comrades with many, friendships that have lasted to this day. Foremost in my newly discovered Alta mafia was Dave Hamre. Dave was just a few years older than me but had abundant ski area seniority and was the director of Alta Snow Safety.

The alpine construction company Dave would later form was contracted to build the Big Sky tram in 1995. At that time I was a newly minted Ph.D. geologist and Dave hired me to assist on the tram project. putting my new degree to use on the geotechnical problems of tram installation. However, before this adventure I was to have one more short stint on the Big Sky ski patrol.

BIG SKY REVISITED

After an adventurous two years at Alta, I found myself back in Bozeman during the last half of the 70s. Jim Kanzler was still the director and offered me a part-time ski patrol job and a place to stay in his mobile home near the Meadow Village. Housing at Big Sky was a bit sparse then. There were new faces on the ski patrol including Reggie Clark (the second female ski patroller I had known), Brad Grine, Gordon Lehman, Mark Kalatowski, Bob Divel, Mike Meyers, and "Extreme Dave" Stutzman. Dave got his title "Extreme Dave" from his mountain climbing exploits and in no small part his personality. This was mostly, but not all, tongue in cheek. Dave and I became good friends and enjoyed many deep powder runs, rock and ice climbs, and a wild mountaineering adventure to China under the leadership of the legendary Fred Beckey, North America's most prolific first ascensionist. Sadly, shortly after returning to Big Sky following the China adventure, where Dave had made a bold technical first ascent on a 23,000+ foot peak with his partner Jim Williams, he was killed in a sidecountry avalanche on Big Sky's Andesite Mountain.

Prior to this China climbing trip, in 1980 I had followed Dave Hamre to Alaska, where he helped set me up with avalanche forecasting and ski patrolling jobs. I suffered a serious knee injury at the Alyeska resort, motivating a career change and eventually resulting in a Ph.D. degree in geology. While it was not within my specialty, my geology studies helped me to deal with some of the geotechnical issues in building the Big Sky tram in 1995. These experiences have all been part of a rewarding full circle, with Lone Mountain in its center.

The installation of the Big Sky tram dramatically changed the character of Lone Mountain and the Big Sky community. Avalanche control routes, hand charge cables, actual ski runs, rope lines, snow fences, and hazard markers all had to be developed from scratch. Questions like these had to be answered:

How many customers could be safely be put on top at one time? How to sweep the enormous area of steep terrain in the frequent whiteouts?

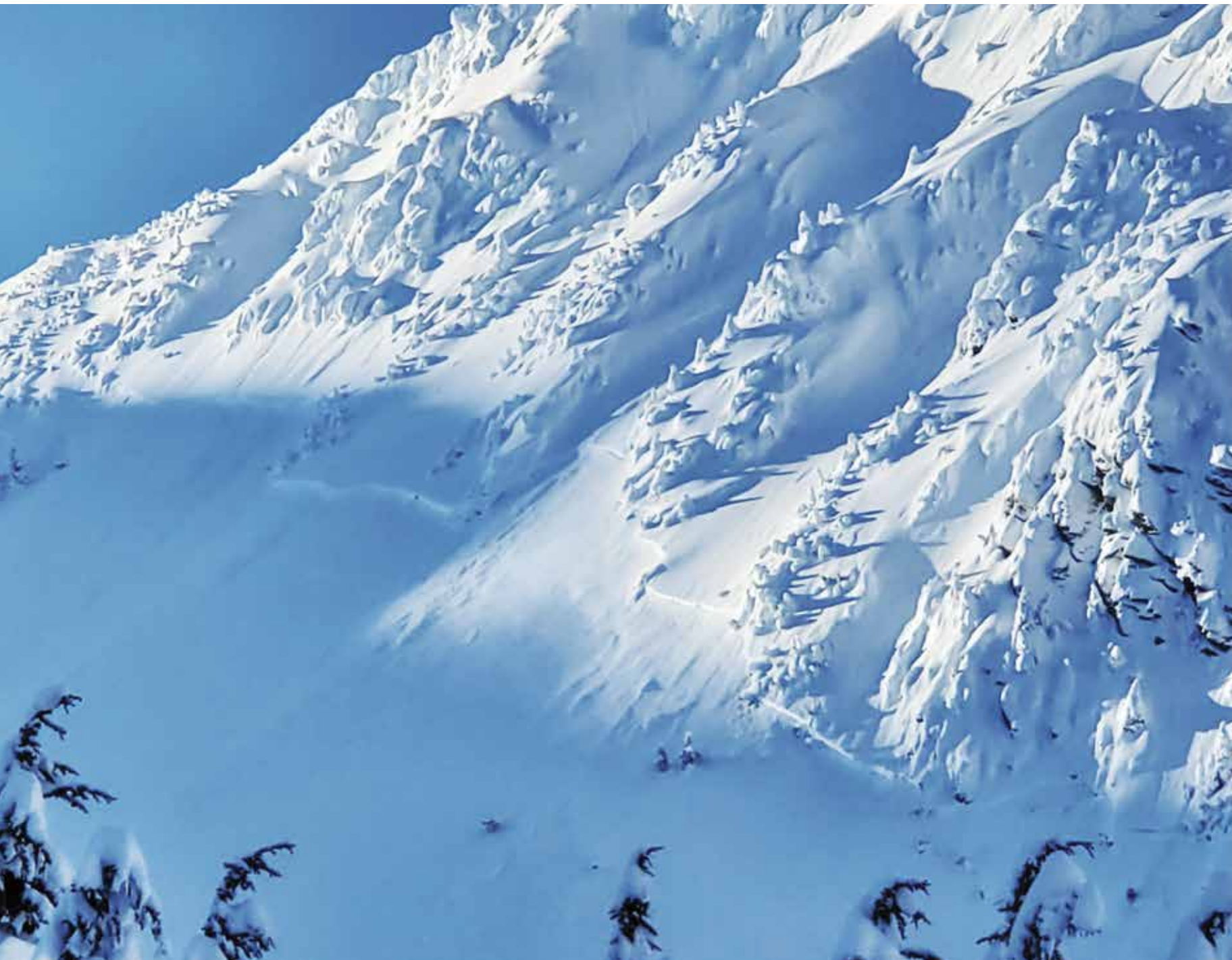
How would injured skiers be evacuated on the steepest slopes? How would the tram cars be evacuated if the lift broke down?

All these things would fall to a new generations of ski patrollers. Foremost in this group were Jim (Jimbo) Humphries and Jon (Yunce) Ueland. While many others such as Bob Dixon, Mike Buotte, Scott Savage, and more, were involved with managing such a serious ski operation, Jimbo and Yunce were pioneers in developing the procedures of how to safely implement public skiing on Lone Mountain. For anyone who has had the privilege of skiing that peak, our hats are off to these guys with much gratitude. ⬢

After flunking out of college his first semester, **DOUGLAS (DOUGAL) MCCARTY** eventually received a BA and MS from the University of Montana, and PhD in geology from Dartmouth. He received The Clay Minerals Society mid-career scientist award for scholarly research in 2011. In between, Dougal worked as a ski patrolman and avalanche forecaster, and kept a hand and foot in the climbing world.

QUESTING QUESTIONS

Searching for clues about the quality of the mind in metaphysics, native cultures, ancient philosophy, behavioral economics, vocabulary, intuition, and science.



Deep Bear Instabilities

BY JEFF MOSKOWITZ

On February 6, 2021, I was out ski touring on a north aspect of the Takshanuk mountains near Haines, Alaska, where at an elevation of 1,500' our group unintentionally disturbed a brown bear den with a sow and cub.

Photo previous page: Haines, Alaska: the lone deep slab. We had been including Persistent Slab as a problem in our forecast for the last two months. As the season evolved there seemed to be a new persistent layer (either NSF or crust facets) every few weeks. As older persistent layers were buried deeper and deeper over time, they tended to crush and bond, and our focus would switch to the newest PWL. There were no avalanches observed on these deeper layers in our area for quite a long time. We finally removed the Persistent problem from the forecast on January 27th. Two days later, we heard about a big natural deep slab. I was able to ski up there after about 3ft of new snowfall had started filling in the crown, but I didn't have time to investigate. I estimate the crown was about 2m deep when it occurred. This slide is remarkable to us for the complete extent of propagation. It was clearly a hard slab, breaking from anchor to anchor. There is some evidence of step-downs within the bed surface but it's hard to tell exactly what layer it ran on. Was this a one-off event? Or is it a harbinger of a future deep slab avalanche problem?
ERIK STEVENS

The snow under our skis was hard and cold temperatures had turned the surface to slippery facets. After adjusting the plan based on the time of day and avalanche conditions, we strapped skis to our backpacks to boot pack through a section of steep icy forest. I remember my partner directly behind me yelling "Bear bear bear!" and, looking down to my left, an enormous head appeared out of the snow. Fight or flight took effect and knowing we had been standing directly over a den, I traversed the slope hard and fast to the left about 20 feet as I looked back in horror. The bear had clawed its way to the surface, with presumably the same fear that overcame us and, in an instant, had grown into an enormous mass of fur. Silhouetted there was my ski partner, with a custom Fairweather Ski Works split-board mounted in an A-frame to his backpack, face to face with a wild animal. The sow shook off its winter stupor and, as time stood still for a moment, the scene erupted as the two entangled and disappeared down the slope and out of sight.

For more than a decade as an avalanche professional, I have been on a literary vision quest deep into a rabbit hole of human factors literature in an attempt to answer dynamic questions that stem from psychology, economics, sociology, and philosophy. My questions involve how we predict not only what is happening in the snow and terrain, but also what is happening in our own heads and those of our partners. These seemed to be most heavily tied to avalanche accidents and close-calls in the mountains that are more easily explained by the failure of snowpack layers. On that day, my friends and I experienced something completely out of the ordinary that could not have been predicted, as Nicholas Taleb coined, a highly improbable *Black Swan* event. As we looked back on the bear incident, one of the main differences between a startling wildlife encounter and triggering an avalanche was that somehow our decisions did not seem related to the outcome as clearly. It seemed to be more of a type of chance, or plain bad luck, a topic that Ed LaChapelle, in his essay *Ascending the Spiral*, insighted needing further investigation in the snow sciences. For me to fully understand the process, I had to leave the physical realm and enter the metaphysical.

Forces in nature have intrinsic factors that are not always perceivable. As avalanche practitioners, we know the clues aren't always obvious and that is why we rely on intuition to see the larger picture. After the bear incident a particular passage came to mind from the book *Deep Survival* by Laurence Gonzalez, about the Native Hawaiian word *Mana*, used to describe a spiritual energy or power, as an ancient survival technique in the sport of surfing. By physically interacting with energy patterns, we can develop a knowledge that ultimately leads to our survival. He goes on to explain that as humans, once we leave a low-risk environment of home and place ourselves in one that forces are beyond ordinary experience, we engage in systems that kick back when you least expect it. *Mana* is a way to learn about those physical forces that might kill us and drives it into our bones, nerves and muscle fibers. The problem for operators of the system becomes that most of the time nothing serious happens and that is what makes it difficult. We tend to believe orderly behavior is the only possible state of the system. Then at the critical boundaries in time and space, components and forces interreact in unexpected ways with catastrophic results.

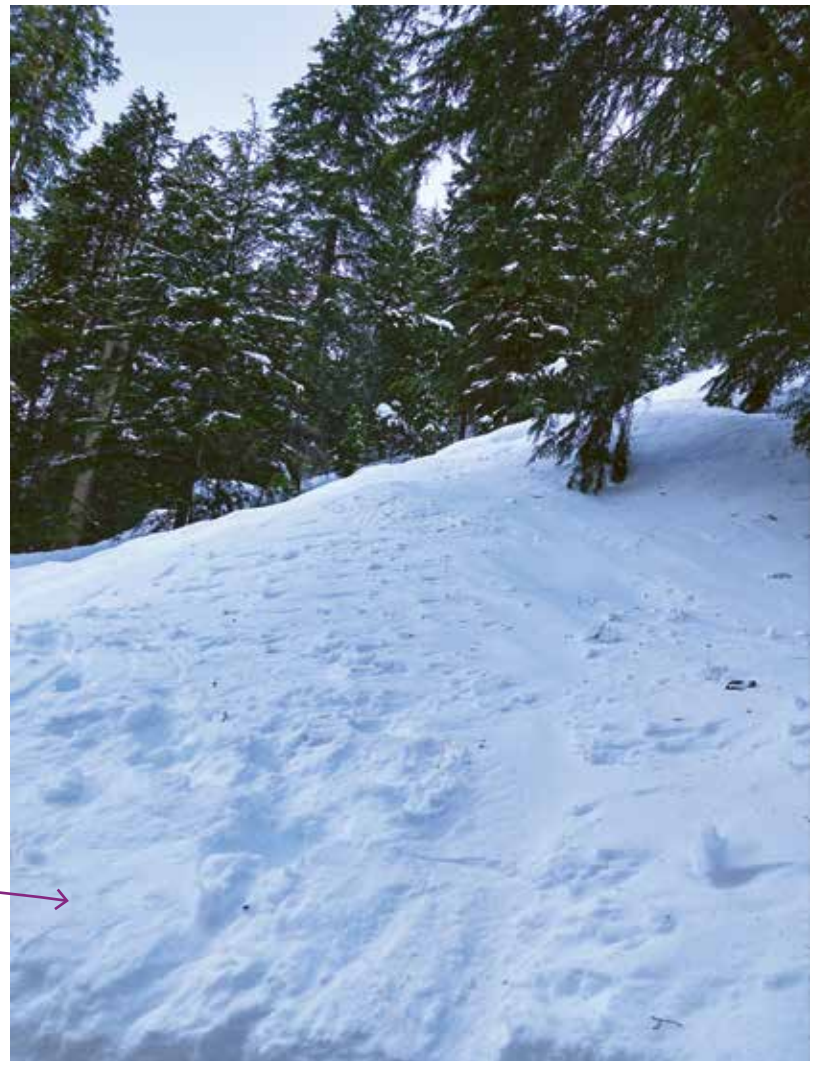
Any decision produces successes and failures; how we can properly discern between the two often boils down to another invisible dimension. Our ability to equate luck into the risk-equation and manage it like surfer's *Mana* is explored in a unique cultural viewpoint of humility and restrain in Richard Nelson's biography, *A Raven's Witness*, by Hank Lentfer. A chapter on Alaska Native Koyukon people's belief in luck is that it is a tangible essence, aura, or condition that holds sway over every aspect of life. By not getting luck means not keeping it. Moreover, luck is about respect and good luck requires proper action. "Keeping luck is a state of grace, less about fortune and more about proper relationships with each animal, plant, every mountain, lake or river slew, and all the shifting moods of weather," Lentfer writes. "Like smoke making wind

visible, luck brought shape to all the forces hovering just beyond the edge of sight, and there were a thousand ways to lose it, once gone, no amount of skill could replace it. In the absence of luck, there is no destiny except failure." The Koyukon relationship to nature is shaped by luck, whether that is the gifts of animal or grace of weather. It is a sentiment that the world is rich with mystery and there is no success without luck.

That day on the mountain culminated in various levels of energy patterns, physical forces and luck hard-wired to our human stress response and sympathetic nervous system. Less than a minute had passed as I braced in full survival mode, unsure if the animal would crest the hill towards me and calling up to my third companion who was slightly above us, notifying him about the gravity of the situation. Immediately the two of us went into companion rescue mode, pulling skins and called for help with our InReach. We could hear our friend speaking to us and followed a bloody trail of broken ski poles down a hundred feet. The bear was nowhere in sight, but knowing it might return, our awareness was heightened. As we assessed the injuries and reported these via satellite communication along with our precise location, a full-bore emergency response was underway. Digging through our packs we committed ourselves, along with our fourth member, a dog, to keeping our partner warm, shouting on occasion for safety, and joking our way through stories to pass the hours away. Three hours later a Coast Guard helicopter broke the silence and after dropping a swimmer and lifting our buddy in a litter, the dog, friend, and I gathered belongings and skied off into the darkness.

A dancing aurora filled the sky that same night and as several days passed, the adrenaline began to wear off and wounds began to heal, surfaced an incredible appreciation for all things. This included the wild country we are fortunate enough to share with the brown bears that inhabit it, and greater symbiotic ecosystem they are connected with. Our preparedness with gear to handle an emergency in the backcountry, training that we had undergone in our careers, and other experiences culminated in luck as we crossed from one boundary into another. Weeks after, local bear biologist Anthony Crupi of the Alaska Department of Fish and Game gave a presentation on brown bear denning characteristics and habitat. We came to find out that their territory and that of the backcountry skier overlap almost exactly: steep, open slopes with good drainage in the trees. The information armed us with knowledge and also nudged local recreationists to carry bear spray even in the winter, to be prepared, travel with a two-way satellite communication device, and realize that we have been lucky before. Knowing what we know now does not change what happened that day. It does change our connection with ourselves, our partners, and our environment. ⬢

WE TEND TO BELIEVE ORDERLY BEHAVIOR IS THE ONLY POSSIBLE STATE OF THE SYSTEM. THEN AT THE CRITICAL BOUNDARIES IN TIME AND SPACE, COMPONENTS AND FORCES INTERREACT IN UNEXPECTED WAYS WITH CATASTROPHIC RESULTS



This 35-degree slope in a canopy opening is where the two slid down about 100 feet, with any trace of evidence washed away from the MH-60 Jayhawk rotor wash.

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Ancient Wisdom for Avalanche Foolishness

BY JERRY JOHNSON

In our paper "Risky positioning—Social Aspirations and Risk-Taking Behavior In Avalanche Terrain", my co-authors Andrea Mannberg, Jordy Hendrikx and I laid out our findings that the desire to gain social status i.e. positionality, is associated with an increased willingness to take risk among backcountry riders. Our analysis is based on data for hypothetical choices from an online survey (N = 648) in North America where we identify "positional riders."

These individuals voluntarily subject themselves to potentially deadly risks during backcountry tours and so may be more likely to experience an avalanche accident or near miss. They do so largely to build status among aspirational groups of skiers with whom they want to be associated.

We find three features of behavior among positionals that are associated with increased risk-seeking (as opposed to risk averse) behaviors: 1. Positional riders are significantly more likely to boast about riding bold lines—especially using social media, 2. They are more likely to associate steep riding with social respect and acceptance, and 3. They are more likely to say that they would accept to ride a potentially risky line if their peers want to ski it. This is all rather disturbing but not surprising if you engage in most any level of social media where there is an autocatalytic cycle of attention seeking, valorization of our actions, and peer acceptance.

A single chemical reaction is said to be autocatalytic if one of the reaction products is also a catalyst for the same or a coupled reaction.

It is also a self-perpetuating process.

While this group of riders does not explain the causes of all accidents, a careful examination of recent events in say, the last ten or so years, suggests that many accidents are not due to ignorance or lack of experience/avalanche education. Rather, it seems more casualties are experienced, educated, and knowledgeable of basic and essential avalanche skills. Put another way—those involved in avalanche accidents have not failed in their technical decision-making skills when they choose to ski risky terrain. They seem to have the snowpack assessment skill that should allow for good decision making. Their failure, if you want to call it that, is in the quality of their mind when they decide to ski a questionable line. And to state my bias right up front—the quality of mind, or lack of, is directly related to the misuse of social media and how it encourages us to surrender our well-being to others. In short, positionals appear to choose to let social affirmation signals override safety concerns. This is not a revolutionary finding.

In this essay I want to explore how we can change the quality of our minds by visiting or revisiting some historical philosophical discussions from the second century that may help us understand how to adapt our thinking with respect to social media. I will draw on teaching of the Stoic philosophers, particularly Roman emperor Marcus Aurelius and philosopher Epictetus, to reframe how we can think about how the need for social affirmation causes us to give up control of our decision process.

The Stoics are enjoying a bit of a surge of popularity, especially during the pandemic. They taught a path to happiness, resilience, and how to be better in our daily lives—all important themes in tumultuous times. Today's positive psychologists like Martin Seligman and Jonathan Haidt, among others, teach that individuals can take positive steps both personally and institutionally to improve the quality of theirs and other's lives; their ideas resonate today in popular culture as flourishing. You may also recognize it as "mindfulness,", "prosperity," or "being in the present." The term Stoics used is eudaimonia (εὐδαιμονία) —literally happiness through practical wisdom.

Psychologists make a distinction between hedonic emotions such as pleasure, satisfaction, and happiness and eudaimonic emotions such as interest, enthusiasm, and engagement. Hedonic emotions elicit an opioid response that floods our brains with a surge of pleasure that has been found in being erotically stimulated, well fed, and from social acceptance. Hedonic emotions are a signal that a goal has successfully been reached. They are the reward emotions.

Dopamine gets us ready for an experience. It is the "wanting" response. Intense exercise is associated with a dopamine surge. So is higher risk taking. When we get to our destination and riding high with enthusiasm research has shown that

Their failure, if you want to call it that, is in the quality of their mind when they decide to ski a questionable line.

activity-induced arousal reduces risk estimates and risk judgments. People engaged in a competitive exercise take more risk in an unrelated task immediately following the exercise. All of this is to say that the quality of our minds is easily influenced by how we are engaged.

Eudaimonic emotions—interest, enthusiasm, and engagement, in contrast, serve as motivational signals that propel one toward a goal. This state of emotion is based less on pleasure than it is in doing things "right." Have you ever backed off a slope and on reflection said—well, that was the right thing to do and then felt good about the decision? That warm feeling is a eudaimonic emotion. Maybe it is a different form of happiness and satisfaction derived from doing something hard rather than doing something simply for fun.

The things you think about determine the quality of your mind. Fundamental to Stoic thinking is the concept of avoiding mental contagion and a primary idea is to pursue life without wasting it on frivolous matters. Your mind is the product of what you think about, and it is easily "tainted" by others. Epictetus puts it this way: if your body was turned over to just anyone, you would doubtless take exception (and seek to take it back) and save it from abuse. Today, we can ask why aren't we ashamed that we have made our mind vulnerable to anyone who happens to criticize us, so that it automatically becomes confused and upset?

This is exactly the role (and business model) of social media that thrives on clicks, hits, and likes. Zuckerberg and Dorsey understand this completely and our emotional responses to clicks, hits, and likes has made them very rich men.

Choose your influencers wisely. We often let outside opinions cloud our behavior and subsequent decision and yet, we often fail to reflect on how that happens. When we respond to comments, we are wasting our time worrying about what other people say, do, or how they act. These are distractions that weaken our focus on making our own decisions and planning our own actions, distractions from living a happy life.

Cal Newport is a computer science professor at Georgetown and author of *Deep Work*. He advocates right mindedness through the lens of uncoupling from the noise of email and social media. It seems obvious that a clear mind, free of random noise, is useful when we make a high consequence decision like skiing a big line in the backcountry or designing a complex algorithm. Such decisions require careful consideration. Newport has several techniques for doing just that.

Epictetus, born around 50 CE in what is modern-day Turkey, puts it this way: "Happiness and freedom begin with a clear understanding of one principle—some things are within your control and some things are not. No man is free who is not master of himself." When we give in to the perceived importance of social media, we quite literally give up our freedom as an individual and relinquish control of fundamental principles of what is important.

Another description of mental distraction is what Marcus Aurelius called "the clacking of tongues." Jonathan Haidt reminded me recently that we all love ourselves more than other people love us but we often care more about their opinion than our own. In doing so we surrender our personal responsibility to ourselves and give over our decision outcomes to others. Tongues clack to ski a line that maybe we think is sketchy, to encourage us to take needless chances, and afterward to respond on or to social media. We too easily play to the clacking crowd and in the process forget why we are in the backcountry in the first place.

The same goes for clapping of the crowd—just another version of a clacking of tongues. Is practicing our craft about other people's recognition? If not, what's left for us to prize? I think it's this: to learn our craft in the pursuit of being stronger, happier, and wiser. When we achieve those goals, we can evolve to be teachers, mentors, and educators. The Stoics believed the same was true for all trades, arts, and lives and that those roles took on important meaning. It comes down to the motivation for our actions—is it internal or externally driven?

Stoics are not egotists. The ego or self-centeredness is a selfish way to make decisions. The ego asks us to think about what's in it for us. Again, the modern reward is often the currency of social media—clicks and likes. Egos usually make poor decisions. Stoics try to free oneself from such emotional baggage through a focus on reason and understanding the natural world. Egos are not good at snowpack analysis.

To blame oneself is proof of progress. What happens when we make a bad decision or worse, have a bad outcome from the decision?

Too often I read technical accident analyses that fall short. We misplace blame on snowpack or weather when those conditions were and are to a large extent knowable and manageable. Digging pits, studying terrain and weather patterns are basic skills all of us possess or can possess given time and commitment. Blame does not belong to the partner that pushed us toward a decision, to a failing snowpack, or to wind loading. Blame lies with us. In policy studies we call these factors proximate (immediate) vs ultimate factors. We are the ultimate factor in any close call or accident. We often blame proximate factors when we should concentrate on the ultimate cause of failure (or success).

That said, at the end of the day Epictetus says blame no one. Rather, set your mind straight and focus on the now, if you can. If not, try to repair the damage done to yourself and your friends and move on. Set a new example by your future actions and chalk up past lessons. An ignorant person is inclined to blame proximate factors for his own misfortune. To blame oneself is proof of progress but in a perfect world the wise man never has to blame another or himself. Try for wisdom. Marcus Aurelius: "Waste no more time arguing what a good person should be. Be one." Other people do not diminish your ability to choose unless you let them. You can choose to influence your friends by your example. Feel affection for people even when they make mistakes. It makes them feel better and accomplishes more progress in setting the mind right—yours and theirs.

The Stoics repeatedly preached four principles as requirements for living a good life. A Stoic believes they don't control the world around them, only how they respond—and that they must always respond with courage, temperance, wisdom, and justice. People who embrace these principles and embed them into their lives will become smarter, stronger, happier, and wiser. I think they also make better decisions.

People who spend a lot of time on social media responding to the clacking tongues and clapping hands are pulled in the opposite direction by four hooks:

A Stoic believes they don't control the world around them, only how they respond—and that they must always respond with courage, temperance, wisdom, and justice.

1. Instead of being wary of social contagion, they expose themselves to the most powerful social contagion engine ever built. By doing so they give up control. Don't give up control.
2. Instead of cultivating focused attention in the service of deep work, they invite distraction, immersing themselves in ever-shifting trivialities. They live their lives in what Nicholas Carr calls "the shallows." Practice noise canceling.
3. Instead of doing their duty and ignoring the crowd, they ask the crowd to shape their behavior through behaviorist methods. They invite strangers to give them thousands of small rewards and punishments. It is a zero-sum outcome and is the essence of positionality. Keeping up with the Joneses is a zero-sum game that you will never win.
4. Instead of turning down judgmentalism and moralism, social media turns them up. Social media encourages quick judgments of others, made in a performative way for an audience that has no concern for context, truth, or justice or your well-being. Social media interactions discourage forgiveness, especially of anyone on the other "team."

MARK WHITE

Social media is a gigantic machine for stamping out stoic virtues and retarding personal growth and safety. It shifts our thinking away from autonomy and self-centeredness and toward the selfishness of more followers and clicks. In the process we place ourselves at risk of positionality and senseless risk.

Is there a "virtuous" social media? I think it is possible. To judge it we need to know the aim or goal. We know it isn't (or shouldn't be) clicks and empty social affirmation. It should expand our knowledge of the world (snowpack, weather, routes, hazards) and it should result in personal happiness and growth rather than ego gratification. It is worth the time of professional avalanche educators to think about how to apply the best features of social media and how it can move us forward.

Responding to clicks and claps is what Nobel economist Richard Thaler discussed in his early discovery of "supposedly irrelevant factors," which refers to something that, in theory, should not affect or influence the thinking of a rational person, but does. Most of us are familiar with many of these SIFs—loss aversion, sunk costs, and narrow framing are the most common. Noise in our head is another one. We know we are easily distracted by clicks and claps and we know that they matter to many of us to some degree. The secret is to not let them overwhelm our mind.

When Marcus Aurelius walked the streets of Rome as emperor of the world's greatest power of the time he would have been cheered on by governors, senators, and his generals. He would have been greeted by clacking. He would have ignored it because he knew it was meaningless and empty and that they would clap for his replacement as well. He would have guarded against hollow flattery and vanity. He would have agreed with a stanza from Longfellow's *Belisarius*:

Ah! vainest of all things
Is the gratitude of kings;
  The plaudits of the crowd
Are but the clatter of feet
At midnight in the street,
  Hollow and restless and loud. ⬢

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Epictetus, *The Enchiridion* ("The Manual"), from the Robert Dobbin translation
Special thanks to Jonathan Haidt

JERRY JOHNSON, left, and Jordy Hendrikx, right, professors at Montana State University, have teamed up with Norway-based, Swedish behavioral economist Andrea Mannberg, center, to research why some people take excessive risks, particularly in avalanche terrain.

Manageability

BY SARAH CARPENTER

For the last 10 years or so, not only have forecast centers been offering a hazard rating, they have also been discussing what avalanche problems are present in their forecast areas. As a backcountry traveler and an avalanche educator, I value the vocabulary of avalanche problems, which offers cues to adjust my terrain choices based on the current conditions.

Since the introduction of the avalanche problems and the additional vocabulary, guide services have moved towards discussing these problems at morning meetings. Some guide services (at least the ones I am a part of), when they talk about the avalanche problems, are also discussing the "manageability" of these avalanche problems. The forecasted avalanche problems, the perceived "manageability" of these problems, and the recent weather and avalanche history guide the day's terrain selection. I have appreciated these conversations. And I also see some cracks in them.

What is meant by "manageability?" And can we really presume to accurately assess the manageability of an avalanche problem before heading out into the mountains? How do we know where the line is and how close we are to it? I've found some of the manageability conversations trend towards an overconfident assessment of how close one can get to that invisible line and not actually step over it.

After listening to these conversations, jumping in at times, and thinking about the term manageability a lot on the skin track, I reached out to several folks to dig deeper into this concept. Thank you to Don Carpenter, Dallas Glass, Dave Richards, and Lynne Wolfe (to name a few of them) for talking through this concept and offering perspective on avalanche forecasting and decision-making and where this term "manageability" fits in.

When I think of the term manageability, three questions come to mind:

- Can I recognize the avalanche problem or problems?
- Can I avoid or eliminate these problems?
- Can I escape an avalanche if triggered?

Over the past many years, the vocabulary of risk has entered the skin track conversation. We discuss our avalanche problems with regards to: likelihood of triggering, consequences of getting caught, our vulnerability in the current (or future situation), and our exposure to the avalanche problem and the terrain. If, during this conversation, our situation appears higher risk than is acceptable, we ideally adjust our terrain or some other element of our travel to lower the risk.

I believe that, as a broad community of backcountry travelers, adding the conversation of "manageability" is doing ourselves a disservice.

> Avalanches are not manageable. However, terrain is. And actions are as well. The goal of the backcountry skier is to manage their terrain and actions at all costs.

As backcountry travelers, we are or should be, for the most part, avalanche avoiders. Over a career of decades, most backcountry travelers see and experience very few avalanches. Because of this lack of experience with avalanches, I don't think that we are very good judges of what is "manageable" and what is not. If you want to gain knowledge and experience about avalanches and "manageability," you have to see a lot of avalanches. Ski patrollers have a much better understanding of "manageability" of avalanche problems because they see a lot of avalanches. They are avalanche hunters, which is distinctly different.

WIND SLABS

Let's dig a little deeper into wind slabs, which is where I see the most variation in people's approaches. Here are a few ideas.

1. **Wind slabs are highly variable.** They can exist on one part of a slope and not on the rest of the slope. They can be hard to recognize, and thus, harder to manage.
   - They can range from shallow to deep (even across one start zone)
   - They range from really soft to pencil or knife hard
   - They form on new soft snow, as well as on persistent weak layers and anything in between.
   - They form in the common start zones, as well as further down the slope, or on one side of the slope with a cross-slope wind.

The range of this problem presents so many challenges. As Don Carpenter asks, "How do you assess a problem that doesn't exist on your approach?" I can think of at least one accident where the party involved walked up into a wind slab problem, which, we assume, that they then triggered from the bottom of the slab. This makes for difficult to impossible forecasting.

2. We **underestimate the likelihood** of triggering a wind slab. Or we underestimate the size of the avalanche problem.

3. We **overestimate our ability to escape** from a wind slab avalanche. Or we underestimate the consequence of the terrain we are in. We think we are better than we are. Or tougher. Or more nimble.

4. We don't **understand the true definition** of manageability
   - How many avalanches have we triggered or been involved with?
   - How many avalanches have we escaped?
   - How many have we not escaped?

I'm guessing that most of us have not triggered many avalanches, which makes it hard for us to realistically assess our ability to escape an avalanche.

Based on these variables, I think gaining an understanding of manageability is a long way off for those of us who aren't triggering avalanches on a regular basis.

Given that not all of us are going to get a job patrolling, we should seek out other ways to gain knowledge about how avalanches truly behave. A few thoughts on ways to do this include:

Talk to people who have been caught in avalanches. Listen carefully to their responses.

- How quickly did everything happen?
- Was there time to react?
- Time to get off the moving slab?
- What was the avalanche problem? How deep was the avalanche? How wide?
- What did you learn?

EAT A SLICE OF HUMBLE PIE

Learn from your mistakes, from your experiences, from your environment, and from your partners.

Strive to be a realist and not a hero. What can you really manage?

Dip your toe in the water and take your time paddling out. Give yourself room to make mistakes. Can you assess smaller and less-consequential pieces of terrain before jumping in the big line? This is an under-utilized technique.

It is amazing to think about the progress that our industry has made in how we talk about snow, avalanches, and risk. I invite all of us to continue to push this conversation forward, and question concepts and vocabulary that offer certainty in a world where snow science continues to be part science and part voodoo magic. To borrow a few thoughts from Dave Richards, "*In my not so humble opinion, avalanches are not manageable. However, terrain is. And actions are as well. The goal of the backcountry skier is to manage their terrain and actions at all costs. If this is done right, you never have to manage the avalanche.*" ⬢

SARAH CARPENTER is an avalanche instructor and ski guide based in the Tetons. As she transitions out of her AAI ownership role, she is spending more time exploring mountains.

Exploration vs. Exploitation

BY MIKE RICHARDSON

Behavioral Economics and Backcountry Skiing

It's Valentine's Day as I finish the final revisions to this article about uncertainty. Most of us know about uncertainty in a romantic context: does he or she like me? This is a type of uncertainty that most of us are familiar with, or at least were familiar with at one time or another in our lives. What do we do when we feel uncertain about someone's romantic interest in us, or lack thereof? Well, many people evaluate conversations and text messages and other interactions, trying to resolve the uncertainty. Sometimes we're even smart enough to ask directly, but politely. Sometimes we get the answer we want, and sometimes we don't.

Unfortunately, at least on the surface, it's not as easy to ask the snowpack if avalanche formation is likely. We're always left with some residual uncertainty, and, over the last 10 years, there has been a resurgence of interest in managing uncertainty in the snow safety community. Late last year, I read a very interesting article about uncertainty in the context of behavioral psychology (*A Primer on Foraging and the Explore/Exploit Trade-Off for Psychiatry Research* https://www.nature.com/articles/npp2017108). Specifically, the article refers to a set of behaviors using the terms *explore* and *exploit*. Explore means looking for opportunities outside our typical surroundings, and exploit means taking advantage of options that we are already familiar with.

Let's put things into context with a direct quote from the article: "*Imagine lunch time has arrived and you must make a decision about what to eat. You can go to the nearby deli and order your usual sandwich, or you could try the new restaurant that just opened next door. What should you do?*" This scenario is very similar to the search for terrain appropriate for conditions. Most winter backcountry recreationists have "go to" terrain that is like the nearby deli. We've spent a lot of time in this terrain, we've tried a lot of the menu items, and we know what we like. In that sense, we could view the *exploit* behavior pattern as having a connection to Ian McCammon's *familiarity* heuristic, and maybe we do this to reduce uncertainty. Perhaps this explains the problems that arise from familiarity: complacency is easy because it's less mentally taxing.

One must be careful to maintain a careful balance between exploiting a known resource and exploring a new one: "*In an uncertain and changing environment, where values of all potential options are unknown and/or the values of these options change over time, one must adapt by flexibly alternating between* ***exploration and exploitation*** *in order to maintain efficient performance over time and to keep track of the state of the environment.*"

February 22, 2021, Granite Canyon, Grand Teton NP. Vol. 40 photo contest entry. BOBBY GRIFFITH

This points out an important, and potentially new, strategy we can use to manage uncertainty in the winter backcountry. "*This duality raises a question of whether explore/exploit decisions are qualitatively different. Exploratory decisions could be separate processes in which automatic, exploitative decisions are actively suppressed in order to consider other possibilities. Alternatively, explore/exploit decisions could be better described as extreme ends of a continuous scale (Berger-Tal et al, 2014; Cohen et al, 2007), too much exploitation could promote habit formation (Beeler et al, 2014), and too much exploration may result in an individual who is 'jack of all trades, but master of none'*." I am particularly interested in the term 'habit formation' because this is almost certainly the fundamental element that enables us to consciously and unconsciously suppress our uncertainty. More importantly, we may also then transfer these habits to unfamiliar terrain. It's also worth noting that the article characterizes exploitive decisions as 'automatic'. Perhaps this means that we really do need to be vigilant to remember that uncertainty always exists, and that we must be extremely careful not to simply march along the lines of our existing habits. This could mean that it's a good idea to consider ourselves as novices again when we find ourselves in unfamiliar terrain. After all, new terrain is definitely more uncertain, and **it is good to be aware that our habits and skills won't and can't always help us be more certain, no matter how we feel.** Or as Lynne Wolfe says, we can measure the contrast here by asking the following questions: "what do you WANT to do? What do you think you OUGHT to do?". There may be another corollary here: as the winter snowpack evolves across space and time, what feels familiar to us may in fact not be familiar at all.

How Conditions Change Us

Instead of 'How Conditions **Change** Us', I could have easily called this section 'How Decisions **Train** Us': we must be conscious that we can make automatic decisions, that decision-making is training, and that our biases can convince us we are making an informed decision when we are not. We must also be mindful that the results of our decisions train us, and this is truly a key finding for me personally. Think of it this way. Imagine that you are at a slot machine with four levers and you have 50 chances to pull one of the levers. What you don't know is that over time, your brain is going to start to discover a pattern, and this, along with your personality characteristics, is going to slowly influence the choices you make. For example, you might begin to learn that the third lever has the highest rewards, but it also carries the most risk. You might learn that the first lever pays small rewards consistently. The implications of this should sound very familiar to almost anyone who has ever planned a backcountry outing. Each decision point is a chance to pull a lever, and over time you develop a sense of the pattern, and therefore your feelings of uncertainty decrease—justified or not. This may reflect an actual reduction in uncertainty, but it doesn't entirely prevent disaster, as much as it might start to feel that way. In other words, even though you start to sense the pattern, and you begin to optimize your decisions for slow, small rewards, can you resist the temptation to go for the big rewards that are sitting right there, just behind the other lever?

In terms of behavioral psychology, **do you continue to choose the lever with slow, small rewards and less uncertainty (exploitation), or do you choose the lever with fast, big rewards and higher uncertainty (exploration)** and, in both cases, how do you know which to choose? Personality traits are key here, along with age and experience of course. It's also important to understand ourselves, to try to understand how the mode we are in, either exploitation or exploration, might influence the outcomes when we try to resolve uncertainty.

The article reveals another key finding: "*A second key parameter is the learning rate, which determines how much prior beliefs determine choice, or the degree by which expectations are updated by the prediction error (ie, the difference between the expected and the actual outcome). A subject's learning rate should be balanced between two extremes of too much influence of prior beliefs or none at all. Each individual's 'gain' and learning rate (among other parameters) influences their explore/exploit tendencies.*" Stated simply, how do we balance our past experiences with the need to be coldly objective today? How are we wired in

this respect? Are we consistent in our ability to make decisions with risk characteristics appropriate for the current situation, or are we using our inner risk propensity, beliefs, and experiences, to unconsciously guide ourselves toward the reward that we prefer? Along that same line, it's important to ask ourselves how much we are learning in a given situation. If we're learning a lot, if we're constantly receiving new information, and if we're 'surprised', then that is definitely a sign that the environment is more wicked than perhaps we had anticipated. This is definitely a sign that we are probably somewhere we don't belong.

Decision Noise

Until reading this article, I was unfamiliar with the concept of 'decision noise.' It was something I had thought about in fuzzy, imprecise terms; something I could never quite put my finger on. I had a vague understanding of what it meant, but I couldn't really explain it in clear terms. I would say that decision noise can be explained in simple terms as repeated, small bouts of uncertainty at key decision points. Or, in other words, decision noise might cause you to find yourself somewhere you would rather not be, asking yourself: 'how exactly did I end up here?' According to the research, "*Not all exploratory decisions are information seeking, sometimes they are the result of random decision noise leading to exploration by chance*." This is exactly what happens on unplanned backcountry ski outings, but I think it's also fair to say that unplanned backcountry ski outings—the classic 'first, you must go see', are the result of random decision noise, which can arise from many diverse factors, and that such outings are also far more likely to be adversely affected by random decision noise. When this happens, it can feel like we're making decisions inside a system or framework for managing risk, when in fact our decisions are simply the accumulation of whatever we felt like doing across a series of moments and places. That is not risk management; that is simply ignoring uncertainty.

Finally, "*In a stable environment in which knowledge of the distant past is relevant to the present, the learning rate should be small; conversely, in a rapidly changing, volatile environment, the learning rate should be larger.*" This precisely describes how we all gamble. Go to point A and we'll make a decision when we get there. But what if, on the route to point A, the very act of traveling, perhaps in good weather with a great group, slowly poisons our objectivity? What if we started out wanting to pull the lever that leads to slow, steady rewards, and we suddenly find ourselves curious about the other lever without knowing why? How good is our information? If we have good information, if we truly know our uncertainty is low, then maybe it's okay to try the other lever. Otherwise, we must be very careful to guard against our curiosity. And sorting situations and decisions into the categories of exploit/explore definitely gives us a new way to think about uncertainty: is this an appropriate time to explore?

New Questions

I started writing this with the idea that I might arrive at some helpful conclusion, but maybe that's not how uncertainty works. Maybe all we have are questions and we must continuously search for the right questions, and ask ourselves these questions over and over again? With that in mind, I would propose adding the following questions to the trip planning phase, and to utilize them at key decision points during a backcountry outing:

- Am I the kind of person who likes to try new things?
- Am I the kind of person who wants to try new things today?
- Do I want to exploit or explore?
- How are my decisions training me today?

It may be worthwhile to ask yourself the following questions:

- Is my core style 'exploit' or 'explore' or both?
- How have my past decisions trained me?
- Is it worthwhile to audit my past decisions through the lens of my personality traits to evaluate my habits and make adjustments?
- How do these factors influence the way I think about and manage uncertainty? ⬢

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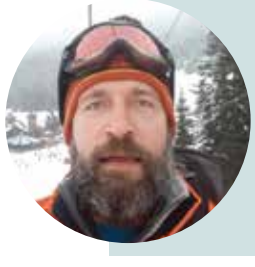

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STOP STRESSING ABOUT STRESS

BY GARY KUEHN & DR. IAN SNAPE

IN ORDER TO MITIGATE RISK

ABSTRACT

A skier riding in trees needs to focus on the gaps while peripherally watching or listening for others. If they focus on the trees then they hit the trees. Similarly a focus on the negative effects of stress (distress) can induce a nocebo effect, creating more distress. This has two implications for risk: distress inhibits high-quality decision-making, and distress is a risk in itself for the health of avalanche professionals.

By focusing on creating and maintaining resilience, we can eliminate the nocebo effect, minimize distress, and improve both risk-based decision making and the wellbeing of avalanche professionals.

Experts miss what they are not looking for. In this case, the avalanche gorilla is focussed on the trees and stress is a consequence. 📷 TIM ULEWICZ AT FRONTLINE MIND

As avalanche professionals, our association with risk is personal. Our decision-making often occurs under pressure, is highly consequential, and most of us have direct experience of loss or trauma. Compared with the general population, the likelihood and consequences of risks are high. As Kristensen & Genswein point out in their 2012 ISSW paper, *Perception of Risk in Avalanche Terrain*, over a professional mountain guide's 40-year career the chance of dying in an avalanche is 1:20, or higher if operating at increased hazard levels in consequential terrain.[1] Eric Haskell & Darcy Solanyk in TAR 40.1 acknowledge that "Professional guides, rescuers, and avalanche forecasters are a unique subset…Their increased exposure to the mountain environment and other party's accidents increase their chances of experiencing physical and psychological trauma."[2]

In such a high risk profession, that role of stress (distress) is clearly critical for risk-based decision-making and as a response to workplace risk factors. However, there are three problems with the term 'stress':

1. Stress means different things to different people. For many, stress is a positive state of anticipation or action—this is commonly referred to as **eustress**. It is common to hear that people need a bit of stress to perform well. While for others, stress is more like the bad type (distress). And of course people can experience both and a wide variety of other states not called stress, as they respond to context in either well adapted or maladapted ways.
2. Stress is entirely created internally. As a term, stress is often used to describe an environment as a cause, or an effect (like a mechanism). Whether eustress or distress, both states are entirely our chosen response to the external environment. Whilst there is a strong correlation between workplace risk factors or adverse life events and stress, this relationship is not causative.[3] Workplace risk factors for stress, burnout, and trauma for avalanche professionals include time pressure, consequential decisions, and death or trauma from friends, colleagues, and family.
3. By focusing on stress (implied to be of the distress kind), we predispose ourselves and others to create those sorts of states through the nocebo effect. Quite literally, stressing about stress creates stress! Excessive internal distress changes the ways our brains function and this is identifiable with neuroimaging and biomarkers. We can also sense the changes ourselves: as increase in blood pressure and heart rate, sweating, inflammation, and speed while decreasing digestion and prefrontal cortex activity (where reasoning and critical thinking are mediated). In turn, that impedes effective decision-making. If we practice distress for a prolonged period, we will become prone to a range of illnesses, especially heart disease and early death.[4,5]

At the 2021 American Mountain Guides annual meeting, Jayson Simons-Jones compared [dis] stress to two scenarios: one being a "rapid loading event… you get 2" SWE overnight and everything falls down no matter how strong the structure is underneath and it's kinda predictable," in the other, "there is incremental loading… 2, 4, 6 inches of snow and maybe a bit of wind and you have the same end result where there can be a catastrophic avalanche."[6]

Expressing stress, burnout, or trauma in terms of snow accumulation events is useful to a point—both single catastrophic events and multiple significant or cumulative events represent different workplace risk factors; however, that's where the comparison stops.

Unlike snow, that passively responds to the environment and our interactions, humans have agency. Snowpack doesn't learn from past events and cannot choose to anneal and become stable, whereas humans can learn and exercise choice. There is no doubt that some people respond with distress when their otherwise resilient state fails to cope, hence the correlation between workplace risk factors and internal distress. Such distress can occur in response to a single

catastrophic event (the one rapid load event), or from many gradual experiences (like incremental snow loading).

"Historically, resilience has been defined as a trait which is a constellation of personal qualities that protects individuals. These protective factors help individuals to withstand the pressure of the environments they are operating in."[7]

In much the same way that we want a snowpack that is resilient, especially to human interactions, "Incremental loading" allows more time for adjustment, healing, and metamorphosis of both the snowpack AND us! A better snowpack structure is more resilient to any loading in the same way that a resilient person's robust base improves their adaptation after external pressures. Persistent weak layers of snow, by definition, take longer to become dormant, and may not be totally safe until flowing in the river.

So rather than focusing or inducing states of stress, is it better to focus on developing resilience. Perhaps we have personal persistent weak layers? If so, one option is to choose safer terrain (with less exposure to workplace risk factors) until we develop resilience (where we can 'anneal' like snow).

For dealing with the prospect of a heavy loading event or seemingly unending storm, we will manage better if we have built an established support network into our structure.

Summary

Stress is an internally created response. It does not adequately describe the environment or the interaction between the environment and our response. An external event that is stressful for one person may be neutral or even beneficial for another. Most importantly, stressing about stress will induce stress through the nocebo effect—instead focus on resilience and what is needed to thrive in the operating context.

Resilience is about having the choice of how to respond to challenges, and potentially having that good stress if it is useful to you. You can prepare yourself for some of life's demands, whether these are many small challenging events or one large challenge.

There will always be change. In seasons with a chronic persistent weak layer problem(s) we can plan for the reawakening of these layers in the spring, and possibly look forward to their transition into the river. Maintaining resilience might be planning for change. It could be a change in focus or an entirely separate career path.

Resilience is about having the choice of how to respond to challenges, and potentially having that good stress if it is useful to you. You can prepare yourself for some of life's demands, whether these are many small challenging events or one large challenge.

Just as we mitigate avalanche risk by awareness, education, developing safe habits, and rescue training, we can mitigate the risk of stress, burnout and trauma by developing resilient habits, and establishing support and recovery systems. And always remembering that it's ok not to go out when the danger rating/workplace has reached 'extreme' hazard. ⬢

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Influence & Motivation

BY RYAN BUTLER
PROJECT CONTRIBUTIONS BY LAURA MAGUIRE, PHD, DENISE MITTEN, PHD, & MATHIEU BROWN

Systemic Influences in Early-Stage Backcountry Users

A popular recent conversation topic in the backcountry skiing and snowboarding community has been the increase in new participants, focusing on common sense questions about this new population: are they prepared and sufficiently educated?

I wanted to learn what motivates and influence this new group, although research and accident data show that, in actuality and counter to initial presuppositions, a more experienced population is the demographic that has been involved in avalanches.

This study specifically researched early-stage backcountry users who have been recreating in the backcountry for five or fewer seasons. The study was broken into two phases, first a survey then interviews with ten randomly selected survey participants who agreed to an interview invitation, giving me an opportunity to inquire into some of the deeper and systemic influences in this user group.

Context is key

The goal of this study is to identify what influences the decision-making process of backcountry users during a typical day of skiing and snowboarding in the mountains, meaning a tour under normal operations and without significant incidents or accidents. Specifically, a systems approach is used to understand influences. Traditionally, decision-making research has focused largely on accident analysis from the sharp end, or first person in-the-moment, perspective. If the influences of human factors are considered from a systems perspective, the analysis is more multifaceted than simply looking at just the sharp end. By exploring the influences involved leading up to and during everyday recreation activities (that is, non-accident scenarios), a deeper understanding of context can be created, which in turn could be utilized to further inform accident analysis and prevention. Rather than asking why a person made a certain decision in the backcountry, this approach attempts to understand what information and experience got them there in the first place.

Who are the new users?

I crafted then distributed a survey in early 2021 to the backcountry community and received roughly 100 qualified responses (with five or fewer years of backcountry experience). Within this group, 56 indicated that they have been skiing or snowboarding in resorts for 10+ years. Of those respondents, 18 had their first backcountry season in 2020–2021. Only seven respondents were completely new to the sport within the last two years. The data shows that the group of early-stage users to the backcountry is technically proficient in their skiing and riding ability, although of course there is the new skillset needed when accessing the backcountry.

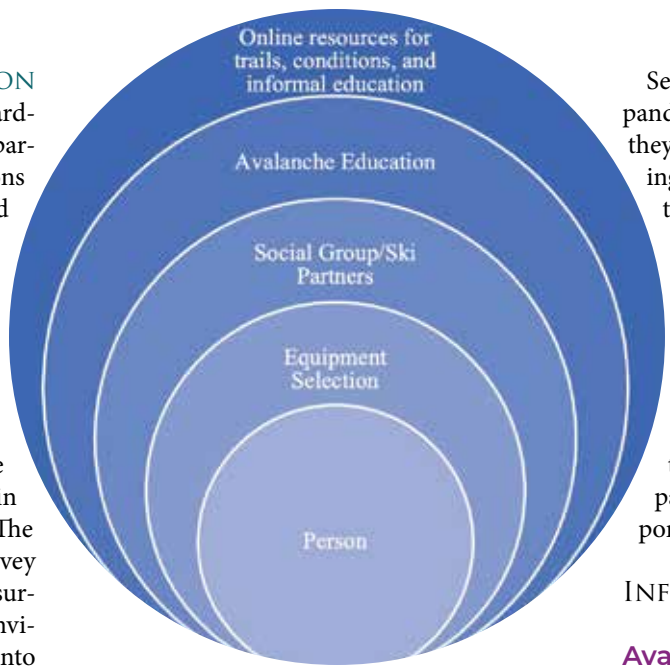

Figure 1: Example illustration of a possible system of influencing factors

COVID-19 Influence

Many in this responding group had their first backcountry season during the pandemic. Is it coincidence or did COVID-19 have a major impact on the number of recreationists looking to the backcountry to get their skiing or riding in? Of all survey respondents, 60% indicated that COVID influenced their recreation choices. A common reason was trying to avoid crowds at the resorts, which had different motivators and reasons behind it. Social distancing, a preventive measure to curb the spread of the pandemic, was one sub-reason for avoiding resorts. Lift lines and lodges are traditionally heavily trafficked zones, so avoiding being close to others can be difficult. The secondary reason to avoid ski resorts was the result of the measures the resorts themselves were taking to slow the spread of the pandemic. Some relied on a reservation system to control the volume of people on the grounds and keep crowding down. This deterred 30% of respondents as there was generally less opportunity to ski at the resort.

Seven survey respondents who indicated the pandemic influenced their ski season mentioned they were more cautious or went skiing or riding less frequently altogether, meaning neither the resort nor the backcountry, to not put any unnecessary strain on the healthcare system. With an average age of 36, this concern was more widespread than for just the older population who could be more susceptible to the pandemic. While a smaller relative result, this is still an important finding. Hospitals in a participant's area had the potential to be at capacity with their COVID-19 patients, so decreasing high-risk activity supported a community-based mindset.

Influences on this group

Avalanche Education

The early-stage backcountry users that participated in this research knew they need the key hardgoods for a rescue: a transceiver, shovel, and probe. In addition, however, this group understood the importance of not going into the backcountry at all without completing an avalanche course. Seventy percent of participants said that they either require a new member of their party to have some level of avalanche education, or that they require it for themselves before going into the backcountry.

In addition, boosting the importance of avalanche education seems to be working. This group knows they need it to make sound decisions in the backcountry. The fact that it is a barrier to entry can pose challenges though. As course demand stays high, survey participants reported that finding a spot in a course can be very challenging and require some added logistics if one is not available locally.

80% of interview participants said that course timing significantly affected their ability to participate in a course. One participant shared that they work a service job in a mountain town, so taking a weekend off during peak season to take an avalanche course is nearly impossible. Acquiring avalanche education can be a cost barrier as well, and a significant one at that, added onto the cost of acquiring all the backcountry-specific gear.

Social Media

The role that social media plays in accessing avalanche information or snowpack conditions appears to have become increasingly powerful. Three (30%) of the interviewees noted that they specifically utilize their local avalanche center's

Instagram page for updates on backcountry conditions. Avalanche centers are utilizing social media to provide valuable information to their forecast regions in new and exciting ways outside of the once daily avalanche bulletin. Catching many backcountry users where they are —on social media— is a fantastic way to keep backcountry users engaged in what is happening in their snowpack if they are not already actively referencing the daily avalanche report. One interviewee said, "I follow [Eastern Sierra Avalanche Center] on Instagram too. So even on days I'm not skiing, I'm sort of in the know with the snowpack and conditions." Four (40%) interview participants indicated that they do not actively follow the daily avalanche bulletin when not actively planning for a trip in the coming days. If important snowpack information was shared more widely and consistently across different platforms, the backcountry user community might have more opportunity to stay up to date on the status of avalanche problems in their local snowpack.

Practical Application

Insights from his study pose opportunities for application in the snow and avalanche fields. The cost and time barriers for avalanche courses have solutions that can be easily implemented. Payment plans for courses was even proposed by an interview participant who said they would be more likely to take the course by spreading the high upfront cost over a more manageable period of time.

Additionally, providing flexible avalanche course dates for the recreation level 1 course could open the door for those who have scheduling difficulties. Many people in resort towns who enjoy getting out into the backcountry are unable to take a weekend off for an avalanche course. As the bulk of the avalanche education courses currently scheduled occur on weekends, this may also open opportunity to create midweek courses when additional instructors are available.

Potential for Future Research

This research identified some future research opportunities. The framework of the study can easily be transposed to the more experienced group, with potential to reveal insights on how human factors and systemic influences evolve through experience. Then with that experience, what makes a person more prone to avalanche incidents? Additionally, where does expertise develop within extended experience? The experienced skiers and snowboarders may be technically proficient in their sport but have the potential to overestimate their avalanche-specific skillset like navigating terrain, mitigating hazards, and keeping cognitive biases in check.

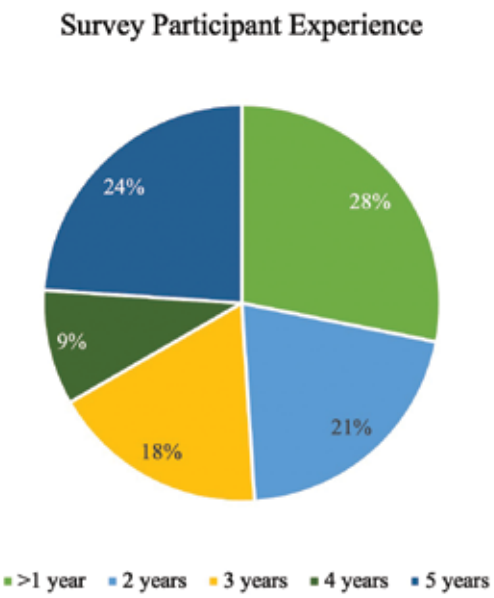

Figure 2: Distribution of Survey Respondent Backcountry Travel Experience Levels, in Number of Years

Addressing barriers within the industry is likely to lead to a user group that is better prepared, informed, and comfortable navigating the complex backcountry.

Conclusion

This target group provided excellent insight and conversation as to their process and influences. These influences are likely not limited to this experience group and could be considered applicable to the entire range of users in this sport. Human factors involved in backcountry skiing and snowboarding are diverse and complex. By having an increased awareness of the systems at play in normal operation, we can better understand how backcountry events occur—this can further lead to better accident analysis and better safety systems. Addressing barriers within the industry is likely to lead to a user group that is better prepared, informed, and comfortable navigating the complex backcountry.

This research was completed as a thesis project for completion of master's study. I am happy to share this the full extent of this work, and a full copy of the research can be requested from me at ryan.butler@student.prescott.edu. ⬢

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RYAN BUTLER is based in the Pacific Northwest and holds his master's in Adventure Education. He can be found volcano skiing, climbing, running, and fly-fishing throughout the region.

WHAT'S IN YOUR (RESCUE) TOOL BOX?

Colorado reacquaints with the Long-Range Receiver

BY DALE ATKINS

When it comes to technology, rescuers are a stubborn lot, often slow to embrace new devices or ideas. While a technology or a device may not always be new, its implementation may be new to an individual rescue team, a region, or even a state. Such is the case in Colorado with the Long-Range Receiver (LRR)—an external avalanche transceiver (457 kHz) antenna that hangs about 15 feet beneath a helicopter. The LRR has been available to rescuers in Colorado for about 10 years, but, remarkably, few knew about it. On a recent sunny and almost spring-like January day, in a mock avalanche search and rescue drill, Alpine Rescue Team, Loveland Ski Patrol and Flight For Life Colorado demonstrated the LRR's capabilities for fellow rescuers, ski patrollers, and also local law enforcement, and the news media.

The LRR is very different than RECCO's Helicopter SAR Detector, and because of confusion between the two devices and technologies, I will briefly mention some information about RECCO's device at the end of this article.

The day's demonstration was a resounding success, opening the eyes of many rescuers and ski patrollers to the benefits of an external antenna. A3's president, Halsted "Hacksaw" Morris, who was on hand, said "The long-range receiver is another great tool for SAR. It will be very useful for searching large scale avalanche debris fields in a quick and efficient manner." Hacksaw is right about that, and there are other circumstances when to use the LLR, too. But before telling about the day's activities and the benefits of a LRR, here is some history and some comments on the challenges of implementing what colloquially is known as a Long-Range Receiver (and any new technology).

WHAT IS THE LONG-RANGE RECEIVER

The LRR is a relatively large (about 6x26 inches) external antenna that hangs a bit below a helicopter; it is connected to a special analog 457 kHz receiver that is then plugged into a helicopter's intercom system. In signal search mode, the pilot performs traditional signal search patterns and listens for the audible "beep" just as a searcher on the ground would do. The LRR is not "directional," so once a signal is heard on the aircraft's intercom system, the pilot makes brackets to complete the coarse search. A practiced pilot can isolate the signal to within a few meters. While hovering over the spot, the pilot instructs a crewmember to drop a weighted "marker" (typically a very large hex nut with a couple of meters of high-visibility flagging). As former flight paramedic and long-time ski patroller Kevin Kelble said in a 2012 newspaper interview, "[W]hat would take you maybe dozens of minutes to cover by ground, we can cover in three to four minutes with a helicopter."

EXTERNAL ANTENNAS

An external avalanche transceiver antenna is not new. The first transceiver prototypes by John Lawton (inventor of the *Skadi*) in 1968 used an external loop antenna. (Thankfully, the unwieldy loop was soon replaced with the small ferrite antenna.)

Jump ahead about 30 years and Swiss avalanche professional Manuel Genswein (then an engineering consultant), in conjunction with Willy Zurkirch of Girsberger Elektronik AG, started work on two external transceiver antennas that could be used to increase the range of an analog transceiver. One was for use by hand and the other could be hung beneath a helicopter. In the fall of 2001 Genswein demonstrated the handheld unit in Croatia at a meeting of the International Commission for Alpine Rescue. Genswein and Zurkirch's devices and the New Zealand practice of simply taping a transceiver to a helicopter skid and splicing in extra wire to the external earpiece so the pilot could listen for the signal caught the attention of several transceiver manufacturers. After several previous iterations, in 2005 Girsberger Elektronik AG released the *VS 2000 Pro*, a transceiver targeted at professional rescuers capable of connecting to a more powerful long-range external antenna. The system—antenna and transceiver—was simply named the *VS 2000 Pro EXT*—EXT for external. In English it became known as the Long-Range Receiver or LRR for short.

OLD IS NEW

The first LRRs deployed in the US went to Utah in December 2006. Later that winter its value was demonstrated in the search and recovery of a buried solo backcountry skier in Big Cottonwood Canyon. Over the next few years several more units were deployed in Wyoming and Washington. Along the way the product was renamed the *HAS457* (and additional units found their way to Montana, and perhaps Alaska and California, too). In 2017 Girsberger overhauled the system and rebranded it as the *HAS457-2*. Despite Colorado having two LRRs since about 2012, the device was and is still virtually unknown.

The reasons for its anonymity include but are not limited to general ignorance amongst rescuers, luddited rescuers (a theme common around the world), a lack of champions, product cost, lack of funding for local search and rescue teams, and a lack of helicopters.

Backcountry SAR in the United States, especially in the western US, has always been very decentralized, so the sharing of information on new technologies, devices, and practices can be often limited. Most participants never knew when new things came along. While the exchange of information has improved greatly in recent years, SAR and ski patrollers—around the world—are well known for their reluctance to embrace new ideas or products. They tend to use and do what was done before. This is also tempered with a bias of *if it wasn't needed in the past, it won't be needed in the future*. If the new device is not incorporated regularly into trainings, it will never get

incorporated into actual incident responses because we play like we practice. With so little knowledge about LRRs, it was difficult to motivate the SAR community for something new.

Cost and need matters, especially for volunteer SAR teams that must find their own funding to support their efforts. While a LRR cost no more than a new 800 Mhz radio, the radio will get used 30–100 times a year. The LRR might get used only once every couple of years. With limited dollars, SAR teams prioritize their purchases of new equipment based on need and their ability to implement a new device or practice, especially devices that need a helicopter.

When it comes to helicopter use for backcountry search and rescue, Colorado lags behind nearly all other states (and the US lags behind much of the rest of the world). The state's high elevations greatly handicap helicopter performance. For example, the median elevation of avalanche accidents in Colorado is 11,600 feet, which is about 2000 feet higher than accidents in Utah and Wyoming, and 3000 feet higher than California and Montana. Being that much higher has a huge impact on helicopter performance, so there are relatively few helicopters in Colorado.

For decades Colorado's Flight For Life (FFL) air ambulance program (and the United States' first helicopter EMS program) has generously provided mountain rescue teams and ski patrollers with helicopter support. In 1992 FFL developed the US's first formal Avalanche Deployment program where their helicopters would pick up two ski patrollers and an avalanche dog, or two mountain rescuers, and fly directly to an accident site to search with transceivers, dog, and RECCO. In 2008 the program had its first live save of a buried avalanche victim. Remarkably, the buried hiker was found and transported to hospital before her companion could even access the debris.

The incorporation of any new device or technology that is used infrequently and irregularly, such as the LRR, into any program is not easy. In FFL's case, regulators do not like things dangling outside an air ambulance helicopter. Even with Utah's Air Methods program paving the way as the first air ambulance program in the US to use the LRR, it still took nearly 18 months to get the FAA (and FFL's helicopter owner's) approval.

Despite purchasing their first two LRRs in 2010, limited training—after approvals—started early in 2012 but stalled after a few years. Interest waned in the LRR as its primary champions had moved on. Also, considering that in the scheme of backcountry SAR, serious avalanche accidents are rare for all but a very few teams. Just after getting the LRRs, the county where it was based experienced a significant downturn in serious avalanche accidents. When the need fell off, interest also faded.

When interest fades, the lack of action is not missed by accountants and pilots. Helicopters are expensive to operate, and flying with the LRR requires flying low and slow. This means operating in an "avoidance" zone where pilots prefer not to fly. In this zone the combination of height (H), velocity (V) and power requirements can render helicopters vulnerable in case of a power loss. In all helicopter flight manuals there is a graphical depiction of the HV diagram. In the business, it is known as the "dead man's curve." No matter where in the world one flies, some pilots are more comfortable than others flying with the LRR (or any external cargo). Learning to use the LRR is expensive, time-consuming, and carries significant added risk. To Flight For Life's credit, they made available the aircraft and pilots for training.

Over the years, in Colorado, all the factors conspired against the LRR, and when something is not used frequently, it tends to get relegated to an upper shelf or to the back of a closet. And that is pretty much what happened to the LRR until a couple of recent busy avalanche winters in Colorado when some new champions emerged within FFL and the Colorado SAR community.

JANUARY 2022 DEMONSTRATION

Currently, FFL Colorado has LRRs at three bases across the state: Denver metro, Summit County, and Durango.

The range of LRRs is a just a bit better than that of modern handheld avalanche transceivers. The HAS457-2 is about 90m, but narrow search strips of 20m are recommended. Searching from the helicopter is best done slowly at about 5km/h. Yes, that does sound very slow, but it is about 4–5 times faster than a rescuer on foot can move across real avalanche debris, especially for an extended period of time.

The LRR weighs only about 6-ish pounds, and this is the main reason it must be flown slowly. It is too light to hang vertically at any speeds faster than a brisk walk. Its tether is short so that it does not get pushed back into the tail rotor. Its light weight, however, makes deployment of the LRR easy, by opening a door and lowering it into position. But using it well—like all technologies—takes significant practice to learn how to use, and how to use it well in real avalanche searches.

FFL Helicopter with LRR. DALE ATKINS

WHEN TO USE IT

To even consider when to use the LRR, the subject must be known to be carrying a turned-on avalanche rescue transceiver. Earlier, Hacksaw pointed out the value of the LRR for large avalanches, but there are other situations when it can also be used. They include but are not limited to:

- Dangerous hang fire because of multiple starting zones
- Dangerous access to debris areas, say benches between cliffs
- Difficult to access debris either because of distance, elevation, terrain, or snow-surface conditions
- Multiple avalanches but unknown which one or even if one contains the missing person

When not to use it:

- The subject is known not to have a transceiver.
- Adverse weather—winds or visibility.
- Rescuers can search the debris before the arrival of the helicopter.
- When rescuers are already on the debris searching or caring for a patient.

At the end of the day, the rescue drill done by the Alpine Rescue Team, Loveland Ski Patrol, and Flight For Life—complete with dogs, RECCO (handheld detectors), LRR, and ending with patient packaging and evacuation—introduced the LRR to many in the Colorado SAR community and to the state of Colorado (Denver's network TV stations and daily paper attended along with several local media outlets, too).

For all it was a new experience to see and work with the LRR, and it was an experience they will not forget. As a result, they will be more likely to request it. At the end of the day, Ethan Greene, director of the Colorado Avalanche Information Center, described the situation well: "The LRR is an important tool for certain avalanche rescue scenarios. More importantly it is an additional tool that rescue groups have at their disposal because the number of rescues and the complexity of some responses are both growing."

LRR IS NOT RECCO

As mentioned earlier the LRR is not the RECCO SAR Helicopter Detector. While both hang beneath a helicopter, the RECCO SAR Helicopter Detector is used to search for lost people year-round. It is big, heavy, and has a much larger range. It is designed to be flown from higher heights and can be flown very fast—upwards of 100km/h. It is a very different device and technology.

For more information about the LRR (HAS457-2), please visit: www.girsberger-elektronik.ch >> products >> HAS457 Helicopter Antenna System.

For more information about the RECCO SAR Helicopter Detector, please visit: www.recco.com >> outdoor rescue.

DALE ATKINS is a long-time avalanche professional with an extensive background in avalanche and mountain rescue.

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BOOKS

The Avalanche Dragons

written and illustrated by Erin C McCrea, with Contributing Editor Fritz Sperry

REVIEW BY LAILA AND AVERY BORICH

T*he Avalanche Dragons*, written and illustrated by Erin C McCrea, with Contributing Editor Fritz Sperry, was published by Mountain MTN Media in 2021. The book is an introduction to the concepts of avalanche awareness and safety for kids. We enjoyed reading this book because it's a fun story that teaches how to navigate through the mountains safely and avoid the dangers of avalanches.

In the story there are two characters, Moose and Goat, who are going to travel through the mountains to deliver food to their friend Old Wise Elk. The author teaches us about the different steps necessary to take before going into the mountains. For example, Moose and Goat's first stop is the Forest Service Ranger Station. Here we learn to gather information about route info, avalanche conditions, and the proper gear needed to carry with us. One important point was to always read the entire forecast and not just the danger level!

Next, Moose and Goat set off on their journey to Old Wise Elk's cabin. Along the way, Moose gets tired. He looks at the map and finds a short cut, but it takes him into more dangerous conditions. When he attempts the short cut, an avalanche dragon awakens and Moose hears the telling 'whumpf' that sends him back to the original planned route. Some of the topics covered are: proper gear, avalanche problem types, route selection, how weather affects the safety of the slope, and how to safely descend a slope.

One really cool thing the author did was to include sidebars called 'Pro Ranger Tips.' These tips helped to summarize some of the more important things to remember. Tips include information about unsafe slope angles, to expect avalanches any time of the year, and to look and listen for signs of avalanche danger.

One thing that confused us was the use of the word 'degree.' For some little kids, this means the outside temperature. In the book, they are talking about how steep a slope is. We had to ask for clarification on this point. Other than that, the book explains the concepts very well for kids of all ages to understand.

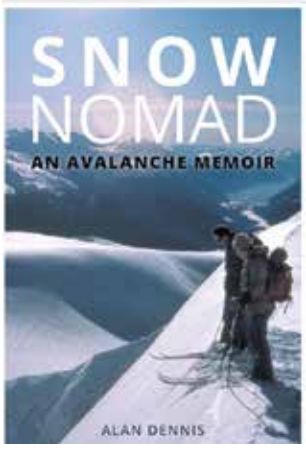
The illustrations in the book are not only fun, but very informative. There is a great picture of a topo map that illustrates the route the characters are following. Also, the drawings of the different types of avalanche problems show very clearly the different ways snow can slide.

In conclusion, we enjoyed this book. We found it easy to understand the concepts of avalanche safety. It would be appropriate for kids of all ages but those between 5 & 10 would really like it. Teenagers can learn from it, too, but it may be a bit elementary for them. ⬢

LAILA (13) and **AVERY** (10) **BORICH** live in Teton Valley, ID. They are homeschooled and enjoy spending their time playing hockey, skiing, mountain biking, and backpacking. They began backcountry skiing when they were 11 and 8. They enjoy making fairy houses in the trees, the quiet of the woods, and skiing the pow pow. They love going to Yellowstone and seeing the animals.

Introducing *Snow Nomad: An Avalanche Memoir*

by Alan Dennis



From bombs to bombillas, *Snow Nomad: An Avalanche Memoir*, chronicles the fifty seasons author Alan Dennis worked in the avalanche patch, traveling between Canada, New Zealand, Scotland, and Argentina. His nomadic account is composed of "facts, factoids, truths, half-truths, rumors, gossip, and fake news."

This unconventional journey on an undulating career path is one riddled with wit and the wisdom he gained when plying his trade at ski resorts, in mining patches, on film sets, and beyond. It's a story of mentors, mishaps, and moments of solitude. Dennis introspectively recalls the times when he was in over his head, but learned to rely on his training, intuition and, perhaps most of all, luck.

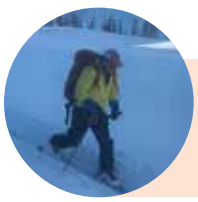
Snow Nomad is a humble and heartfelt tribute to his dear family, friends, and colleagues (and sometimes even foes) with whom he shared these decades, whether shooting military artillery for avalanche control in Canada's remote reaches, scrambling up a summit in the Scottish Highlands, or bunking at a mining camp in Argentina's Andes.

"Alan Dennis is not the only maverick working with avalanches, but he may be the only one to have forecast avalanches for 50 winters while hopping between four continents. This is a wonderful, quirky romp through his amazing career with avalanches, people and tales that should not be forgotten."

—Bruce Jamieson, Professor Emeritus University of Calgary, avalanche researcher and educator

Born in Malta to a British family, the son of a Royal Navy officer, Alan Dennis never predicted he'd spend five decades working in the field of avalanche safety, much less being lured back to the snow after "retiring" at age 51. He primarily worked for organizations such as the Canadian Avalanche Association and Scottish Avalanche Information Service.

After finally giving up avalanches for good, Dennis took to the water aboard his boat, S/V Griffin, named in honor of his father's seafaring days.



ALAN DENNIS lives with his dog in Revelstoke, British Columbia. *Snow Nomad: An Avalanche Memoir* is his first and only book.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The arrogance of humans:
 Thinking we own
Snowfall's time and space...
Squeezing it into
 tidy predictions
As if magic
 could be contained
In the smallness
 Of a box...

Perhaps
 That's what makes the
Snowflakes dance?
Laughing mischievously
As they toss their frosty locks
 In defiance
 Of what we know...

What
 Do
  We
   Know?

All I know,
 Is that I want to lose myself
  In their music,
Spin wildly amidst
 Their crystalline wings
Burn in the torrent
 Of their effervescent sparkle
Then sift, settle, sinter
 On down ~
Joined at once
 To the presence of now.

—Brooke Elizabeth Edwards
11/29/21

FROM READERS:

Congratulations to Patrick Wright of Inversion Labs and his wife Lucille Rice on their baby Madeleine Wright, born 9/19/21! An early supporter of A3.

Bill Williamson with his new puppy Troy, who is probably a whole lot bigger now.

At an ISSW long ago and far away, with Sue's special TAR wine and the first TAR t-shirts. L to R: Mark Moore, Sue Ferguson, Steve Conger, and Craig Sterbenz. 📷 COURTESY STEVE CONGER

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