THE Avalanche REVIEW

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Temperature Effects

Alexander Basin
March 5, 2012

I do remember that the day before I had the largest collapse of my life on a south-facing aspect in that area. It sounded like a land mine going off.

Photo by Todd Glew

Toward the end of my level 1 avalanche course in 1989 in Jackson, I asked Rod Newcomb to explain the effects of temperature changes on the snowpack. I know he responded with the classic avalanche instructor answer of "it depends," and proceeded to list off a few variables that it would depend upon. But as a level 1 student I didn't really get his answer; I had no understanding of the growth and development of the mountain snowpack, hadn't seen that many, and didn't know what to pay attention to.

Twenty-four years later, I still find myself asking avalanche professionals to explain the effects of temperature change on the mountain snowpack. I've seen the lifespan of a few more snowpacks, but remain on a quest for people who can convey the subtleties of "it depends."

The broad-based theme of this issue began to evolve from a notable concentration of presentations at the Anchorage ISSW on effects of temperature change, effects on snow movement and whether that results in avalanche release. Then Drew Hardesty's fascinating "perfect storm" case study (see page 22) at USAW gave a face and location to the warming portion of theory. Dramatic photos from that Wasatch natural cycle helped fill gaps in my grasp of the phenomenon, and then I had the luxury of asking some of the most diligent researchers and thinkers in our field to contribute further insight to what became another science-based TAR theme: temperature effects on snowpack.

In his memorable quote from "Winning the Avalanche Game," Ed LaChapelle reminds us that "Any rapid change in the mechanical or thermal energy state of the snowpack is a precursor to avalanching. And I emphasize rapid."

Starting on page 24, recent research gives nuance to Ed's rapid change, in both warming- and cooling-linked events. Check out the clear and informative paper that Jürg Schweitzer and associates from SLF bring to the table; next, peruse an excellent paper from the prolific Thomas Exner of the ASARC group in Calgary. And if by this time your full brain needs a road map, read Ron Simenhois's essay, which clearly explains how each puzzle piece of warming and cooling fits into the whole.

In addition, Doug Chabot recounts his experience and thoughts on temperature effects at altitude, and Penny Goddard opens our eyes to her work in Canada and New Zealand on cooling-effect avalanches; each of those two is replete with impressive photos. We are also able to bring you a window into past conversations about warming effects, taken from discussion notes at an avalanche conference in Banff in 1976. Goes to show that we are always standing on someone's shoulders in this field. Thanks to Tom Kimbrough and Ron Perla for logistics and insight on this conversation that Drew unearthed while researching his article.

From all of these perspectives, the primary factor that I can hold and then take into practical decision-making situations out in the field is the comprehension that warming and cooling are most dangerous and notable when they are drastic in their extremes, or influence an already-susceptible snowpack. If I already have poor structure and a fresh load, rising temperature can accelerate movement, concentrating stress between adjacent layers, and decrease strength subtly but perceptibly.

—Lynne Wolfe, editor

The Avalanche Review
P.O. Box 2831
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in this issue

Put bluntly, the concept of comparative fault is perhaps best understood as the "moron on the skin track" rule. If you choose to climb the gut of that steep chute on a day of considerable danger and you are injured in a slide initiated by another skier, you are partially at fault because you failed to exercise reasonable care in choosing to climb the slide path.

—Rich Mrazik, *How to Avoid Liability*, pg 31

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The mission of the AAA is:

A. To provide information about snow and avalanches;

B. To represent the professional interests of the United States avalanche community;

C. To contribute toward high standards of professional competence and ethics for persons engaged in avalanche activities;

D. To exchange technical information and maintain communications among persons engaged in avalanche activities;

E. To provide direction for, promote, and support avalanche education in the US;

F. To promote research and development in avalanche safety.

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from the executive director

Mark Mueller Steps Down After 12 Years

Mark Mueller in a rare moment of relaxation on the deck of his Pass Creek yurt near Pagosa Springs, CO.

By now I hope winter has found everyone and I hope it is going well with all of you. No matter what branch of the avalanche tree we are sitting on, we all love winter and those first few days and weeks out in the white are very renewing.

The planned move to an online database management system called Wild Apricot has been delayed, but is still in the works for this spring. Getting everything to work correctly has taken a little more tweaking than expected, but this will be a great tool for AAA. Look for news about this in the spring issue of TAR and also in emails from the Association. Some of you received a test renewal email that was sent in error in October while testing the system. Sorry for any confusion this caused. The main advantage that Wild Apricot will bring to AAA is to cut down on the administrative time and cost that handling membership and subscription renewals requires. I think it we be a great time saver and increase efficiency and that means devoting your dues toward membership benefits.

After twelve years as executive director I will be stepping down at the end of this winter. I have enjoyed the time spent representing AAA, but most especially I have enjoyed the friendships I've made over the years working with a great group of avalanche pros on the AAA Governing Board. I've also enjoyed having the opportunity to put a face with a name at one of the snow rendezvous like ISSW after speaking with you on the phone or exchanging emails. I want to thank all the people who have devoted their time and energy running AAA as members of the Governing Board and I want to welcome those new board members who began their tenure in January.

There's plenty of winter to go; please be careful, and make sure you have some fun.

—Mark Mueller, AAA executive director

from the editor

Lynne and the Chili-dog find some uncomplicated powder skiing in the Teton backcountry, early season, winter 2012/13. *Photo by Kevin Grove*

TAR Warms Up to Temperature Topic

Arctic temperatures continue to rot our snowpack and trouble my toes. I can't get enough to eat to stay warm, and I start to sound like Eeyore in my avalanche forecasting class: "Today's snow surface is tomorrow's buried layer, and when we do get pattern change, it's gonna come crashing down around our ears." By the time you read this, we'll be in the middle of it, trying to forecast how this drought layer will react to new load. That's the fun and the challenge of it, right? But after knee surgery in October, I'd just like some uncomplicated powder skiing; is that too much to ask?

This issue of TAR brings you a wide range of theory and practice. Our central theme revolves around temperature effects, and looks at the topic from a variety of perspectives. I give an overview of the theme in the cover introduction, and you can find the body of the temperature effects articles starting on page 22.

To balance that strong dose of science, we have an impressive photographic tour of the archipelago of Svalbard, an archipelago at the very north of Norway; a look at boundary policies in the Pacific Northwest; and an insightful and entertaining look at real-life skier liability from Rich Mrazik, an attorney who is also the chairman of the board of the Friends of the Utah Avalanche Center. We also have our annual reports on the fall "SAW" (regional snow and avalanche workshop) season; the AAA is proud to support these continuing education seminars as benefits for not just our members.

TAR and the entire avalanche community congratulate Mark Moore on his retirement from a landmark career at the Northwest Avalanche Center. A ream of historical and entertaining photos accompany limericks, anecdotes, and a heartfelt tribute to Mark from his long-time friend Craig Sterbenz.

A short note regarding the upcoming April TAR, 31-4. If you have a case study or thoughts on decision-making, human factors, risk tolerance, or related topics, then start writing right away; deadline for submissions for that issue is February 15, please.

And finally, I'd like to highlight Mark Mueller's essay for "From the Executive Director," above. In this TAR he humbly submits his resignation from the vital post of AAA Executive Director, effective over the summer. The AAA Governing Board is busy behind the scenes scheming how to fill his very large shoes; is this a job that your skill set and personality might fit? Look for a job description and deadlines in the April TAR and on the AAA Web site.

—Lynne Wolfe


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Avalanche Problems & Public Advisories

2/15/12 CAIC Backcountry Avalanche Forecast for Vail & Summit County

PUBLIC ADVISORIES

in this issue

corrections

Cover Avalanche Produced In-Bounds

The caption for the cover shot of the last TAR [31-2] says that the avalanche was produced by the BSP outside their ski area, when in fact we triggered it on a control route on Snow White (inside the area). Not at all a big deal but I just thought you might like to know.

—Duke Barlow, Breckenridge Ski Patrol

aaa news

Certified Instructor Program to Include Continuing Professional Development

Story by Brad Sawtell

The Certified Instructor (CI) Program was created to recognize those who dedicate their careers to educating others about avalanches. To become an American Avalanche Association Certified Instructor is not easy; it takes time and dedication. Applicants must meet the following criteria:

Practical Snow Experience
- 10 years of teaching experience in the snow

Snow Science and Theory
- 10 years of experience and education studying snow and avalanches

Teaching Skills
- 10 years of teaching about snow and avalanches

Letters of Reference
- at least three letters of reference supporting applicants' achievements

Complete application requirements can be downloaded from the AAA Web site by clicking on the sidebar link at www.americanavalancheassociation.org/edu_instructor.php

The CI program is now evolving to recognize those who not only dedicate their careers to educating others, but also continue to improve their knowledge, skills, and abilities. The application requirements will remain the same, but the AAA board and I propose the addition of Continuing Professional Development (CPD) requirements.

CPD is important to ensure competency and is common in most professions. It is a way for professionals to maintain and improve their knowledge and skills. We propose the term for current and future CIs to be three years, and during this time each CI will need to fulfill CPD credit hours in three categories.

We created a matrix for each of these three categories. Most likely there will be topics in the matrix that we have not thought of. No worries; there are plenty of "open" categories. We are more interested in furthering your education as an educator than in checking boxes. The CPD categories include:

1. Teaching
2. Continuing Education
3. Mentorship

Hopefully all current CIs already satisfy the proposed CPD requirements. For active avalanche educators, these CPD topics are readily obtainable during their routine professional activities. But by implementing the CPD requirements, the value of being a CI will truly be an ongoing accomplishment, recognized by the AAA, and seen as a standard of excellence by recreationists and fellow professionals alike. CIs who do not fulfill CPD credit hours will still be recognized for past achievement, though they will likely be considered "inactive" or "emeritus" Certified Instructors.

Program administration will require additional oversight from the Certified Instructor Chair and the Education Committee. We propose an annual audit system, requesting supporting documents from 10% of the CI pool to validate CPD hours. In support, starting in 2015, CIs will need to pay an additional $50 once every three years to maintain their current CI status. Applicants in 2013 will need to re-certify in 2016, and so on.

We are asking a lot of those who become a CI, and in return the AAA has a responsibility to promote the value of CI status. To this end, we are working to create messaging and seek promotional vehicles to explain how AAA Certified Instructors represent the best of the best, and why education programs and participants should seek out CIs.

The CPD matrix draft is available for current CIs to look through. Please contact me with your questions, concerns, or suggestions: Brad Sawtell, AAA Certified Instructor Rep, Education Committee snosaw@gmail.com

Thank You Donors

AAA thanks the following members for contributing an additional donation in 2012 to further our efforts:

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metamorphism

Condolences

Our deepest condolences to the family, friends, and co-workers of the two ski patrollers who died in the line of duty at the end of 2012.

Bill Foster passed away after he succumbed to injuries resulting from an avalanche on December 24, 2012. Bill patrolled for 24 years at Alpine Meadows and six years previously at Northstar. Due to Bill's 20-year involvement in Alpine Meadows' Avalanche Rescue Dog Program, Bill's family feels that the Humane Society of Truckee-Tahoe or the Sierra Avalanche Center would be appropriate recipients of your donations.

Forty-nine-year-old **Patricia "Patsy" Hileman**, of Snowmass Village, a 26-year veteran of the Snowmass ski patrol, was killed December 30, 2012, while skiing alone in Ship's Prow Glades, a permanently closed area at Snowmass ski area, according to a statement from Skico. She triggered a small avalanche that swept her over a cliff. Friends and family who wish remember Patsy are invited to make contributions to the Patricia Hileman Memorial Fund, which will go toward the creation of a public memorial in the Snowmass Village area commemorating Patsy's life and her love for the outdoors. Please make checks payable to "Patricia Hileman Memorial Fund" and mail them to: Alpine Bank, C/O Patricia Hileman Memorial Fund, P.O. Box 5490, Snowmass Village, CO 81615.

Rob Hammel took a break from patrol duties for a scenic photo at the top of Chair 6 at Alyeska Resort during spring 2012. *Photo by Raina Hammel*

Rob Hammel Remembered for Dedication to Family, Work and Others

Story by Rorie, Raina, and Ryan Hammel with assistance and materials from Rich Segal, Alyeska Snowsafety and Alaska DOT

Rob enjoyed Grand Targhee's powder during a patrol exchange in 2002.

A modern Renaissance man and champion of the Alaskan dream, Robert Warren Hammel – long-time resident of Girdwood and Denali Park, Alaska – died on November 24, 2012. Rob lost his life heroically assisting at a motor vehicle accident south of Girdwood while working for the State of Alaska Department of Transportation. Rob died as he lived, with sincere dedication to helping others and a commitment to humanity and justice. He was 60 years old.

Rob was born in Madison, Wisconsin, on June 30, 1952. He graduated from Madison West High School in 1970, then matriculated at the University of Wisconsin Stevens Point. He met the love of his life, Rorie, at the orientation dance on the first day of school.

Rob was a brilliant man with a free spirit. He graduated with a bachelor's degree in political science and then attended law school at Marquette University. Not finding the justice that he sought in the law, Rob left Marquette to obtain his teaching certificate. In college, Rob had discovered the joy of skiing at nearby Rib Mountain, where he joined the National Ski Patrol in 1972 and began the trajectory that would inform the remainder of his life.

In 1975, Rob realized his dream of moving north to the Last Frontier. He packed up "Harvey," his three-on-the-tree Rambler with an extra radiator, AM radio, two extra headlights, and four extra rimmed tires. Rob reinforced Harvey's undercarriage with sheet metal and, with an "Alaska or Bust" sign mounted on his trailer, set out for the AlCan. At the Canadian border, Rob was denied entry because he lacked the requisite $300 cash to proceed. In the face of his father's reticence, Rob's mom wired him the money in secret.

Rob arrived in Girdwood where he quickly began working his way up the ranks at Alyeska Resort. Starting as a "liftie," bumping chairs for $3.50/hour, Rob soon got a job driving snowcats and took pride in grooming perfect corduroy. His attention to detail and unparalleled work ethic were noticed, and it was not long before Rob was offered a position on the professional ski patrol at Alyeska. Rob remained a proud member of the Alyeska ski patrol for nearly 40 years, attending refresher training only days before his death. As a patroller, Rob learned the skill of avalanche control


Rob enjoyed avalanche-hazard mitigation duties throughout the years.
left photo courtesy of the Hammel family; right photo by Reid Bahnson

through the tactical use of explosives, becoming a recognized expert in the field.

Rob leveraged the experience that he gained driving snowcats in the winter into a summer job operating heavy equipment in Denali National Park. Rob took pride in his precise work driving a road grader with nimble skill along the 90-mile dirt road from the east end of the park to Wonder Lake in the Kantishna district. After completing her licensure as a registered nurse, Rorie visited Rob in Alaska for the first time in 1976. Rob gave Rorie her first glimpse of Mt McKinley and the Alaska Range from the back of his Yamaha motorcycle as they drove out to Wonder Lake together. Rorie moved to Alaska the following year.

Rob and Rorie were married in Wisconsin on October 23, 1982, after 11 years of courtship. They spent every summer from 1976 to 2000 together in a 12x16' single-room, government-issued cabin at Wonder Lake in Denali, joined by their daughter Raina (born in 1985) and son Ryan (born in 1987).

Rob and Rorie built their home in Girdwood with the help of friends, initially starting with a two-room cabin and making additions as their family grew. For over 20 years they lived without running water, rigging a pump to water jugs hauled from the local fire station and the Aid Room at Alyeska.

Rob's significant experience with avalanche safety and control earned him great respect among snow-safety professionals throughout the world. In order to focus on this passion and to spend more time with his family, Rob left his summer position in Denali for a full-time job with the DOT in 2000. Since that time, Rob had been a gunner for the Seward Highway avalanche program and for the Alyeska ski patrol, performing forecasting and avalanche-hazard reduction. In the summer, he worked on a specialized bridge crew that traveled the state.

Rob was a man who believed fervently in the nobility of hard work, and his actions mirrored his ideals. Though he worked full time for the DOT, he also patrolled part time at Alyeska as much as possible. In addition to his official responsibilities, Rob became notorious for conscientiously completing a myriad of unenviable tasks and enthusiastically taking on special pet projects wherever he observed something that he could improve. Rob worked more than he played, but he delighted in his time at Alyeska while patrolling and free-skiing with his wife and kids.

Rob spent a great amount of time reflecting on the morality of the world and his role within it. He always took the time to offer his gorgeous smile; his hearty laugh and friendly hello; and his enormous, weathered, yet gentle helping hands to a friend, neighbor, or a stranger in need. Rob was a compassionate, thoughtful, and decent man who will be forever missed and timelessly admired by all who knew him.

Above all, Rob was a family man whose greatest joy was spending time with his beautiful wife, Rorie, and guiding his kids Raina, Ryan, and his son-in-law Rich as they grew into strong, smart, and empathetic adults. Rob and Rorie joyfully celebrated their thirtieth wedding anniversary on October 23, 2012.

An incredible outpouring of love and respect for Rob was expressed by several hundred people who attended his memorial service on December 1 at the United Methodist Church in Girdwood, which Rob helped to build. The service was officiated by Pastor Jim Doepken, Rob's personal friend, who shared tributes of their time rocking out to Neil Young over the church's new speaker system, as well as offering spiritual inspiration.

A magnificent celebration of Rob's life followed at the Challenge Alaska building on the slopes of Alyeska, complete with a torchlight parade performed by the Alyeska ski patrol and a stout bonfire.

In lieu of flowers, the Hammel family has requested that donations be sent in Rob's honor to the Friends of the Chugach Avalanche Information Center (www.cnfaic.org/friends/friends.php), an organization Rob passionately supported. Most of all, the Hammel family asks that Rob be remembered by acts of small kindnesses to others that may initially seem negligible, but as they have learned, do have lasting and heartfelt effects on those who received these same small offerings of humanity from Rob. ❄

After the memorial service for Rob Hammel on December 1, Alyeska patrollers dedicated a torchlight parade in his honor, then pitched their flares into a well-soaked pile of pallets for a whooping start to a memorial bonfire. *Photo courtesy Hammel family*

what's new

A panelist's-eye view from USAW.

Utah Snow and Avalanche Workshop Grows

Story by Craig Gordon
Photos by Bruce Tremper

In partnership with the AAA and Xinsurance, the Utah Avalanche Center offered a practitioner-packed agenda for attendees of this year's Utah Snow and Avalanche Workshop (USAW). Held in a funky, downtown nightclub for the past four years, USAW had outgrown its humble beginnings. Bursting at the seams and looking for a new home, we packed up camp and rolled out the red carpet at the South Towne Expo Center. It was a wild success…now we had room to roam!

The day's tone was set by a catered breakfast of coffee, tea, fresh juice, pastries, and yogurt/granola parfaits. Snow-safety professionals and high-end backcountry users from the Intermountain region were greeted by 20 industry vendors demonstrating their latest products.

The morning was an invite-only, professional-development session for snow-safety professionals from Utah, Idaho, Nevada, Colorado, Montana, and Wyoming. The theme revolved around weak snow issues we all dealt with last winter, kicked off by 20-year patrol veteran Kellie Hunsaker describing her close call on an early morning route at Snowbird, then segued into Matt Wieland's bootpacking research into its effect on stability. Drew Hardesty, Pete Maleski, and Mark Sauer delivered an awesome array of presentations focusing on wet-slab activity, using local stream-flow gauges to help forecast for these deceptively challenging dragons. After a mid-morning break, entertaining insight from Jonathon Spitzer addressed the challenges guides face when dealing with deep-slab instabilities at Ruby Mountains Heli-Experience. Updates from both Chris Covington and Chantel Astorga on the challenges of forecasting for high-traffic DOT operations in both populated and more remote regions wrapped up the session.

Crowds of USAW attendees visit the vendor booths.

Attendees stretched their legs and their bellies thanks to the very generous lunch provided by Xinsurance, with plenty of time to socialize and catch up with old friends.

The afternoon session was open to the public, which was kicked off by a 20-minute video recapping Utah's previous crazy winter. Produced by Trent Meisenheimer and Craig Gordon, the footage and soundtrack kicked ass and had everyone riveted. Presentations focusing on information overload, decision-making, close calls, and sadly, avalanche fatalities followed, hitting everyone right between the eyes. Brett Kobernik, Gabe Garcia, Bob Comey, Josh Anderson, and Jake Hutchinson delivered powerful and thought-provoking commentary, giving everyone pause to reflect on the previous season's events.

Friends of the Utah Avalanche Center president and attorney extraordinaire Rich Mrazik's dialog of legalities surrounding a slide in the backcountry had us talking about our responsibilities as a community. The conversation continued with Bruce Tremper chairing a backcountry round table featuring Paul Diegel, Matt McKee, Jay Pistono, Mark Mueller, and Simon Trautman. The day wrapped up with Doug Richmond revisiting "Mistakes Made by Avalanche Professionals…18 years later."

Mastermind, organizer, emcee, and Utah Avalanche Center forecaster, Craig Gordon, couldn't be happier with this year's turnout. Gordon summed up the event during media interviews, "The fifth annual Utah Snow and Avalanche Workshop has grown from a 200-person event to nearly 650 people attending this year. USAW brings avalanche professionals and high-end backcountry users together for a day of informative, well-rounded, and easily digestible avalanche presentations."

At the end of the workshop, beers and munchies were hoisted as old friends and new made plans for the future. Meanwhile, Craig slipped out of his tux, took his beautiful wife Anita by the hand, and boarded a plane bound for the aqua-blue waters of the Caribbean. He's already planning next year's USAW gig, and invites everyone to join him on Saturday, November 2, 2013. Formal wear not required.

Successful Second Year for Northern Rockies Avalanche Safety Workshop

Story by Erich Peitzsch and Ted Steiner

right: Karl Birkeland clarifies the role of different stability tests in decision-making. *Photo by Erich Peitzsch*

Three esteemed avalanche hunters, a meteorologist, a freeskier, and an ex-Navy SEAL walk into a room in Montana. The result was a spectacular second annual Northern Rockies Avalanche Safety Workshop (NRASW) held October 13 in Whitefish, Montana. In the same vein as last year, the event was a one-day regional avalanche-safety gathering that featured guest speakers, vendor displays/demonstrations, lots of awesome raffle prizes, and over 260 attendees. The workshop featured six speakers under a broad theme of decision-making and the tools used to make decisions. A festive post-workshop social event took place at Casey's Bar and Grill.

Organizing the workshop was a bit less daunting the second time around, and we were fortunate to once again meet this task with a dedicated, positive, and tireless volunteer steering committee. Thanks! Also, NRASW could not have taken place without the support of our sponsors. First and foremost being the American Avalanche Association. Once again, the AAA was the first organization to step in and provide funding, and we express our sincerest gratitude to AAA for their generous assistance. We would also like to recognize additional financial assistance for the workshop provided by the Flathead Nordic Ski Patrol, Big Mountain Ski Patrol, Glacier Country Avalanche Center, Whitefish Community Foundation, and the national office of the National Ski Patrol.

In all, 42 financial and in-kind sponsors supported NRASW. The workshop audience was comprised of avalanche industry professionals as well as winter backcountry enthusiasts from western Montana and Idaho. Vendors included local retailers as well as nationally based avalanche safety equipment and winter sports gear manufacturers.

The speaker line-up featured six outstanding and diverse guest speakers. Scott Savage, currently of the Sawtooth National Forest Avalanche Center, started the day off right, marvelling the crowd with a compelling presentation discussing near-misses of avalanche professionals. He discussed the importance of communication, recognizing limitations, and the effect of perceived and real pressure. His ruminations on psychological theory in decision-making entertained professionals and backcountry enthusiasts alike.

The next speaker, LeeAnn Allegretto, is a meteorologist with the National Weather Service in Missoula and is the avalanche program leader in that office. She started off by showcasing the plenitude of useful resources the NWS makes available to the backcountry recreating community. She then discussed various typical storm patterns common to northwest Montana and how to identify these types of systems through radar and satellite imagery. She ended the session with a broad prognostication of the age-old question: "How much will it snow this winter?"

A host of sponsors and event supporters exhibit their wares at the second annual NRASW. *Photo by Erich Peitzsch*

Karl Birkeland, director of the National Avalanche Center, rounded out the morning with a rousing presentation on the state of affairs regarding field stability tests, when we should use certain types, and how to carefully interpret each one. His remarkable ability to transfer complex research results into practical terms kept the crowd intrigued at every bend. Karl's analogy that choosing not to dig a snowpit is akin to walking across the street and only looking one way (instead of in all directions) was a crowd favorite.

After lunch, Elyse Saugstad, a professional freeskier, spoke about her experiences in the well-publicized avalanche incident in Tunnel Creek in the Washington Cascades. She discussed her group's decision-making process and how the events unfolded. Her moving presentation rang true for many audience members.

Next, Chris Robinson, ex-Navy SEAL, former professional patroller, and search and rescue member, gave an overview of decision-making in stressful situations. He provided fantastic examples of how to "front-load" information in such scenarios to improve sound-decision-making speed.

Ending the day, Dale Atkins, current president of AAA and employee of Recco AB, presented thought-provoking ideas regarding the role of risk and uncertainty in backcountry decision-making processes. He examined how typical risk management in avalanche terrain can be complex and how new ways of viewing risk may help alleviate confusion during these processes.

NRASW profits were donated back to local nonprofit avalanche-education groups as well as to our local winter backcountry winter rescue group, Flathead Nordic Ski Patrol.

This was yet another informative and enjoyable event, and we hope to see you next year. Please visit the NRASW Web site for more information at www.avalanchesafetyworkshop.com.

Ted is based in Whitefish, MT, and has been involved with outdoor education, winter rescue, and avalanche-related work since the mid-1980s. He continues to work professionally as an avalanche educator and forecaster.

Erich is on the steering committee for the NRASW and an avalanche forecaster and scientist for the USGS in Glacier National Park. He may or may not have written this article with baby spit-up on his shirt.

NSP Welcomes Rick Grubin

Congratulations to Rick Grubin for being chosen as the Rocky Mountain Division Avalanche Program Supervisor, replacing Ed Carlson.

Rick is a professional member of AAA and is the outgoing member representative of the AAA governing board. He held this position from 2008 to 2012. Rick is also a qualified AIARE 1 course leader and instructor and a qualified AIARE 2 course instructor. He also serves on AIARE's advisory committee. Rick is certified as an NSP Level 1 and Level 2 instructor and has been appointed as an avalanche instructor trainer. Rick took over as the Loveland Snow Safety Advisor in 2010 and managed to move that program forward in dramatic fashion. He has also done an outstanding job as the RMD Eastern Region Avalanche Program Supervisor since taking over in 2009. Rick's attention to detail and organizational skills will serve him well replacing Ed.

Rick Grubin tells TAR that conditions in this photo were the result of a hit-and-run by a car while cycling home from the market: Broke the fall with my face (it got worse :-).

The National Ski Patrol sincerely thanks Ed Carlson for the great job he's done these past 11 years as the program supervisor, and supports him in his next endeavor.

Eastern Snow and Avalanche Workshop Includes Presenters from the Northeast & Beyond

Story by Jonathan S Shefftz

The second annual Eastern Snow and Avalanche Workshop (ESAW) was held November 10 in North Conway, NH, near the base of Mount Washington in the Presidential Range.

This year's ESAW was once again a collaborative effort between Mount Washington Avalanche Center Lead Snow Ranger Chris Joosen and AAA Eastern Representative Kyle Tyler. The workshop had a strong attendance of 85, even despite a two-thirds increase in the registration fee to bring in speakers from outside the region. The $75 per-attendee registration fee was supplemented with a $500 grant from the American Avalanche Association, and registration fee proceeds over and above the hosting costs went to the White Mountain Avalanche Education Fund to educate children in the northeast about avalanches.

As with similar workshops in other regions, the presentations appealed to a mix of snow professionals and enthusiastic recreationists. Chris started off the event by promising that the presentations would not merely be lecturing at us, but would include some topics just for fun and sheer interest. He reflected that breakthroughs in snow safety do not occur overnight; often a seemingly obscure topic at the International Snow and Science Workshop will develop into a major innovation years later.

Eric Lutz, a PhD snow scientist with the Dartmouth College Glaciology Group, explained the art and science of snow penetrometry, which he described at the onset as essentially just poking around in the snow. He then took us from the earliest such examples as documented at SkiPoleHistory.com from about 6000 years ago, to the ramsonde in the 1930s, the resistograph in the 1960s, the digital resistograph in the 1980s, and the SnowMicroPen in the 1990s.

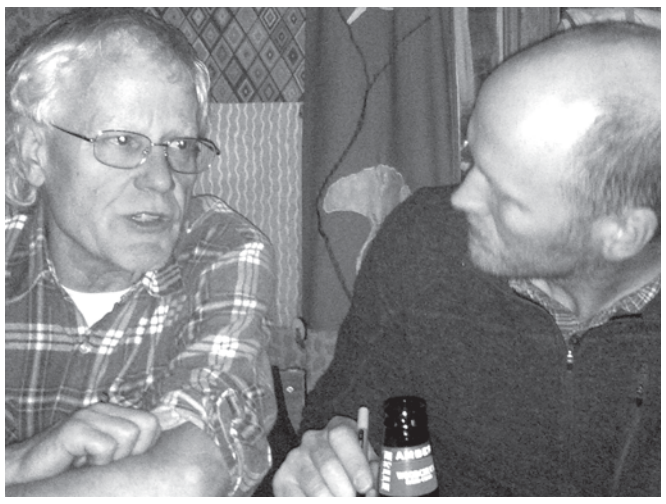
Julie LeBlanc explained her work as a forecaster with the avalanche center in Quebec's Haute-Gaspésie (AKA the Chic-Chocs), the only avalanche forecast center east of the Rockies other than our own Mount Washington. She provided background on the surprisingly deadly history of mainly non-recreationist avalanches in Quebec, with 73 fatalities since 1825. For example, a 1999 avalanche took nine lives in a native village. The initiative for an avalanche center for skiing touring in the Gaspé Peninsula did not start until 1999, and the first public bulletin was issued in 2002 – perhaps the only bilingual avalanche bulletin in North America. Outreach to school children is extensive, to 185 students in its first year in 2012, and aiming to reach 500 in 2013. Incidentally, Julie's Québécois accent contrasted nicely to the American male presenters!

Chris Joosen moderated a panel discussion on wet-snow avalanches with USFS snow ranger Brian Johnston and two presenters from other sessions. Our dense winter windslabs and crusts are less susceptible to the springtime wet slides typical of other avalanche climates. However, the danger of relying on generalities was reinforced by a picture of a wet slide blowout in Tuckerman Ravine with 30' high flanks! So as with any avalanche climate, the specifics in play that day trump any general season-long tendencies.

Next were five sessions packed into a single hour, including snow ranger Jeff Lane summarizing various researchers' weather and snow-related research projects in the Northeast (adding the word "ecogeomorphological" to our vocabularies), Eric Lutz on climate change's effect on snowpack and hydrology, NY Department of Environmental Conservation Adirondack High Peaks ranger Jim Giglinto on the first winter's experience with the new landslide paths created by Hurricane Irene, Blase Reardon on the operations of his Sawtooth Avalanche Center (which includes a surprising extent of avalanche terrain for non-recreationists), and finally Eric Lutz and Chris Joosen on use of the avalanche tiltboard for educating school-age students. Yes, all of this material could have easily been expanded into an entire day's worth of sessions!

After lunch, Blase Reardon took us on a "Journey to the Inner Mind" with how an avalanche forecaster thinks about avalanche safety. His primary advisory goal is to communicate the "one to two ways people are most likely to die" and also define appropriate terrain with travel advice. Blase emphasized the lesser uncertainty about what constitutes the avalanche problem as opposed to the far more uncertain probability of triggering. As an example he focused on wind slab versus deep slab, highlighting the differences between the two for both predictability and consequences.

Blase however went far beyond how a forecaster thinks about avalanches, into really how we should all think about avalanche safety, drawing on everything from the latest insights in the field of behavioral economics to the hand-washing checklist we had all just noticed in the boys' room in our elementary school host. Avalanche safety previously was centered on the Go/No-Go decision paradigm, with the goal that more information and education help backcountry skiers in their roles as rational decision-makers. But in reality, the human relationship with risk is far more complicated, and the divided self has many competing functions. Risk assessments are often far from rational or objective, and fatal accidents occur amidst many obvious warning signs.



left: At the post-ESAW social hour, Sam Colbeck, retired avalanche scientist from CRREL, visits with Eric Lutz, who, in addition to his many other hats, reviews applications for AAA research grants. TAR wants to know what Sam is talking about.
photo by Blase Reardon

below: The obligatory social hour (and then some) featured an airbag deployment by Jimmy Surrette.
photo by Bob Taylor

Furthermore, the backcountry snowpack does not provide a consistent environment with regular feedback, but rather its feedback is inconsistent and often fatal. (Remember Bruce Tremper's analogy of playing soccer in a mine field.) "Experts" are often just those who have gotten lucky over time, just like many stock pickers who have beaten the market over a selected time period.

How to discipline oneself in such an environment? Minimize the number of decisions, thereby allowing fewer opportunities to make mistakes. This applies even to just packing for a ski tour (especially for a groggy avalanche forecaster heading out early in the morning). Another example: put the skin track in the right place every time, regardless of stability conditions, and just rule out some skin tracks no matter what you think the stability might be that particular day. Focus on what kind of information you can know with more accuracy, more certainty, and more often. Strive to obtain feedback from good partners and from notes, i.e., yourself. And remember, the more definitions you have for a successful ski tour, the more likely you are to survive (as opposed to always wanting to ski steep powder).

Blase described his avalanche courses as somewhat of a bait-and-switch: students want to learn about snow, but really he teaches them about…themselves. And indeed this presentation was similar in that we expected a journey to the inner mind of an avalanche forecaster, but he instead took us on a journey into our own minds.

Jesse Williams, who obtained his IFMGA pin this past season and guides for his own Cloudsplitter Mountain Guides, presented on avalanche terrain in New York's Adirondacks, focusing on a guide's methodology for recognizing and avoiding hazard, which includes slope-scale forecasting. Although almost entirely below treeline, the 'Dacks have very thin soil, and hence are prone to massive summer-time landslides down to bedrock. These paths offer excellent backcountry skiing routes – with 16 more created last September by Hurricane Irene's 13" of rain – but also allow for winter snow avalanches. As Jesse noted while addressing the critical issue of whether a slope can avalanche, if a slope can't even hold onto its own trees, then it can't hold onto its snow either. Jesse also emphasized slope-scale forecasting in his guide to terrain selection and stability evaluation.

Sam Colbeck, who retired from the US Army's Cold Region Research and Engineering Laboratory after three decades of groundbreaking cold lab research in snow-crystal bonding, explained (to the extent we could understand) some technical snow physics. And finally, USFS snow ranger Jeff Lane described recent developments in avalanche-safety equipment, highlighting his likes and dislikes.

Interspersed throughout the day, prizes donated by our sponsors were raffled off. Prize donors included American Institute for Avalanche Research and Education, Backcountry Access, *Backcountry Magazine*, Cyberspace Avalanche Center, Genuine Guide Gear, GU Sports, *Off-Piste Magazine*, Ortovox, Rab, SmartWool, Smith Optics, Toko, and Voile.

ESAW finally adjourned down the street to our second host, International Mountain Equipment, for socializing amidst vendor displays from Backcountry Access, Black Diamond, Genuine Guide Gear, La Sportiva, and Petzl.

Jonathan Shefftz lives with his wife and mondopoint-size 15 daughter (still too small for "Tech"-compatible ski-touring boots) in western Massachusetts, where he patrols at Northfield Mountain and Mount Greylock. He is an AIARE-qualified instructor, NSP avalanche instructor, and AAA governing board member. When he is not searching out elusive freshies in southern New England, he works as a financial economics consultant and has been qualified as an expert witness in federal agency administrative court, US District Court, and state courts. He can be reached at jshefftz@post.harvard.edu.

Turns out the author's daughter wasn't just messing around with a ski pole last winter, but was engaging in snow penetrometry.
photo by Jonathan Shefftz

Colorado Snow and Avalanche Workshop Draws a Big Crowd

Story by Scott Toepfer

The Colorado Avalanche Information Center (CAIC) put on the eleventh annual Colorado Snow and Avalanche Workshop (CSAW) at the National Mining Hall of Fame ballroom in Leadville on October 19. The spacious hall is the current home for CSAW, although this year's ~450 attendees nearly filled it to capacity. The Leadville venue is attractive due to its central location in the state, and perfect weather certainly helped highlight the annual event. A climb up one of Colorado's highest peaks or a rewarding tour of the Mining Museum added an additional bonus for those wishing to turn the workshop into a multi-day trip.

The event began at 8am, though by 7:20am only a dozen or so people had arrived (making the organizers just a touch nervous). It didn't take long, however, for the flood gates to open and the ballroom was almost full by the time CAIC director Ethan Greene took the stage to start the festivities. Popularity, ease of access, and low cost make this event a no-brainer for avalanche professionals looking to further their knowledge of snow, mountain weather, avalanches, and explosives.

The 2012/13 season also marks the fortieth anniversary of a structured avalanche-forecasting program in Colorado, and a retrospective of those 40 years was a focus of the event. Way back in 1972, Mario "Pete" Martinelli hired Art Judson at the Rocky Mountain Range and Experiment Station based in Fort Collins. Art was given the task of developing a network of weather and avalanche observers across the state which would allow for a nascent avalanche-forecasting program. Art was tenacious in this project. He was not afraid to wake an observer up with a phone call at any time of the day or night requesting data. This dedication resulted in the first avalanche-forecasting program in North America. We were lucky that Art was able to travel from Steamboat to relate the genesis of avalanche forecasting in Colorado and how he steered it toward the program it is today.

Nick Logan, a retired CAIC forecaster, reviewed the most recent 20 years of the program, and Ray Mumford, mitigation specialist with Colorado's Department of Transportation, reviewed CDOT's reduction program through the years.

The historical perspective was not the only topic for discussion. Grant Statham, Mountain Risks Specialist for Parks Canada, traveled south from Canmore, Alberta, for two talks on hazard evaluation and risk awareness and how to get more out of a public avalanche-forecasting system. He covered the Parks Canada and Canadian Avalanche Centre's implementation of the AvalX forecasting system, along with some lessons learned from rolling out a new public advisory format. Grant's talks bookended several other presentations. Nolan Doeskin, Colorado's state climatologist presented findings on the difficulty of measuring snow and

Now in its eleventh year, CSAW has filled the Leadville Mining Hall of Fame ballroom to near-capacity for the last several years. *photo courtesy CAIC*

how that can skew incoming data and its effects on climatology studies. Over the last 40 years Nolan and the state's climatology department have accumulated an impressive statewide database of weather numbers.

Of course, CSAW would not be complete without the annual look ahead at winter snowfall. Joe Ramey, with the National Weather Service in Grand Junction, delivered his usual excellent look at the patterns developing across the Pacific Ocean that generally drive our winter weather. His prognosis for Colorado was not good, but nobody threw tomatoes. Most decided to rely on faith this year instead.

Other speakers included Robyn Wooldridge, a past Snomass ski patroller and current Montana State University graduate student. Robyn presented results concerning the effects of explosives on the snowpack. Will Barrett with the Breckenridge ski patrol reviewed last season's ski patrol program of public avalanche talks. And finally, Joe Busto looked into the weather-modification program that oversees cloud-seeding efforts in Colorado.

CSAW would not be possible without the support of our sponsors. The Summit Foundation, based in Breckenridge, and the American Avalanche Association have both been long-time contributors to the success of CSAW. The Friends of CAIC have been a big help in filling this event every year. Critical contributors NOVO coffee from Denver and Safeway's bakery and doughnut department are also vitally important. And finally, the participants who come year after year are the primary reason the workshop has become such a popular event.

Scott Toepfer is a forecaster for the CAIC. He works hard to make CSAW a success.

K2 Sports Aquires Backcountry Access

Complementing its industry-leading roster of 14 outdoor recreational equipment brands, K2 Sports this month closed the acquisition of Backcountry Access (BCA), a pioneering designer, manufacturer, and champion of backcountry snow-safety equipment and education.

The move reinforces K2 Sports' position as a global leader in year-round outdoor recreation. With the acquisition of BCA, K2 Sports will be able to reach a wider spectrum of wintersports enthusiasts; from in-area and out-of-bounds, to mechanized and human-powered recreation.

"BCA fits perfectly within the K2 Sports family of brands and rounds out our portfolio as we continue to grow our leadership in winter sports," said Anthony De Rocco, President and CEO of K2 Sports. "BCA is a leader in research, engineering and snow-safety education and has pioneered landmark backcountry safety equipment such as the Tracker avalanche transceiver and Float airbags, among other important innovations."

Pairing BCA's authenticity and snow-safety innovation with K2's investment and global infrastructure will bolster BCA's research and development efforts and create a much wider impact with its commitment to backcountry safety and education.

De Rocco said synergies of the acquisition include global distribution, research and development, supply chain, sourcing efficiencies and manufacturing strengths.

"Like K2 Sports, BCA carries a pure commitment to upholding and furthering the skiing and riding culture and ultimately, serving the specialty retailer. It's not just about selling products, it's about furthering the passion and core philosophy we all share to enjoy snowsports whether you're in bounds or out of bounds," De Rocco said.

BCA was founded by Bruce "Bruno" McGowan and Bruce "Edge" Edgerly in 1994, with a mission to help safeguard the lives of people enjoying the backcountry through product innovation, scientific research and educational efforts. Along with the Tracker beacon and Float airbags, its products include avalanche shovels, probes, snow study tools, backcountry packs and climbing skins, among other gear. BCA's headquarters is located in Boulder, Colo. The company employs about 45 people.

McGowan said K2 Sports is committed to keeping BCA operationally intact and that the acquisition will not change BCA's core market focus.

"There's not much of a boundary now between lift access and backcountry. There are so many people chasing powder now who don't understand the risks of skiing or riding in the backcountry," McGowan said. "K2 Sports gives us a platform to innovate further on a product level while concurrently casting a wider net with our scientific research and snow-safety education efforts.

"We'll be able to reach and engage more people with a hybrid effort of product innovation and snow-safety education," he said.

K2 Sports celebrated its 50th anniversary in 2012. The company's snowsports brands include: K2 Ski, Line Skis, Full Tilt Boots, K2 Snowboards, Ride Snowboards, 5150, Morrow, Madshus, Tubbs Snowshoes, Atlas Snowshoes, Powderidge Snowshoes, and Little Bear Snowshoes.

About K2 Sports

K2 Sports, based in Seattle, WA, has achieved unparalleled success through innovative product offerings, marketing programs, and multiple brand acquisitions. The company operates 14 brands and is globally renowned for its non-traditional advertising, graphics, and high performance products throughout its portfolio. With wholly owned subsidiaries in Canada, Central Europe, Japan, Korea, and Scandinavia and distribution in more than 60 countries, K2 Sports continues to assert its position as a global leader across multiple categories of sporting goods. For more information, visit www.k2sports.com. K2 Sports is a part of Jarden Corporation (NYSE: JAH)

About BCA

Backcountry Access (BCA) is a leading manufacturer of snow-safety equipment, based in Boulder, CO. Best known for revolutionizing the snow-safety industry with the Tracker DTS – the world's first digital avalanche beacon – BCA has most recently pioneered the growing backcountry market with the introduction of its popular Float airbag line. BCA believes that knowledge and education are equally as important as the products it develops, which is why all BCA products are supported by an extensive education program. BCA products are sold in just under 1,000 retail shops in North America and in 27 countries worldwide. For more information, visit www.backcountryaccess.com

Ullr Labs Makes Major Improvements to its Avalanche Safety Mobile Apps

Scott and Bob at Ullr Labs (www.ullrlabs.com) have been busy with major improvements to their Mobile Avalanche Safety Technology for smart phones and tablets. Last season, several Avalanche Center forecasters recorded and shared observations in their region, and provided space on their Web sites where other MAST users could add their observations too.

This year the Northwest Weather and Avalanche Center is displaying Ullr Labs observations on their site using a direct application interface developed with Scott's help. This allows NWAC to directly and easily ingest observations from Ullr Labs or other apps directly in to their forecasting workflow. They have also developed with the other Avalanche Centers methods to easily review and display their field reports of snow and avalanche conditions.

After releasing MAST for Android in late summer, they added several features to both versions, including:

- Audio, video, photos and text files can now be attached to pit profiles and stability test results. These files can be transmitted to the avalanche centers and sent by email or messaging service to a defined set of people.
- For iPhones with Siri, MAST converts voice dictation to text notes – no more typing on a tiny keyboard in freezing conditions.
- The OGRS shear scale, the Propagation Saw Test, and the ability to record pit layer depths from the bottom up.
- Viewing other observations in a list and on a map, including the video, photos, audio, and text files.

More and more avalanche centers receive field observations via smart phones, which extend a forecaster's view into current conditions. Here are some guidelines the centers suggest so that users can get the most useful information:

1. Keep it simple. Observers should focus on weather conditions, obvious signs of instability and actual avalanches. While fun to record, a recreationist's pit profiles or stability test results aren't as interesting to forecasters as reports of worsening weather, collapsing layers or actual slides.
2. Include photos, videos, audio, and text notes with the observation. As they say, a picture is worth a thousand words. MAST's Photo Feature automatically records date, time, aspect, slope angle and location. The app also lets users attach video clips, photos, audio and text notes to their observations.
3. Include contact information so the forecasters can follow up. They respect your privacy and will not use or display your contact information without your permission.

Ullr Labs hopes everyone shares their observations with the Avalanche Centers and their friends. AIARE instructors, AAI instructors, and Avalanche Center personnel can get MAST free by emailing Ullr@UllrLabs.com. "Crowd-sourcing leads to smarter decisions" they said. "We want to make it easy to have fun and be safe."

Gazex Phases Out Artillery in Little Cottonwood Canyon

Story & Photo by Chris Covington

The Utah Department of Transportation has directed its avalanche-safety program to reduce its dependence on military artillery for conducting avalanche-control work. Because of a higher level of concern over artillery fragmentation pieces, a greater concern about the risks of firing rounds over inhabited buildings, an increasing number of people skiing and snowboarding in the starting zones where the artillery is fired, and an increasing financial cost in maintaining an artillery program, UDOT has begun a process to replace some of their artillery targets with Gazex installations.

Of 18 avalanche programs in the US where artillery is used, only UDOT in Little Cottonwood Canyon fires artillery rounds over inhabited buildings. The US Army has given approval for this practice to continue, but concerns about the risks contributed to UDOT's decision to seek an alternative method of control work.

In Little Cottonwood Canyon, where an average of 500 artillery rounds are fired into the starting zones of the highway avalanche paths each season, several of the targets are within a linear distance of 500m from inhabited buildings. Though it is unknown exactly how far fragments of exploded artillery rounds travel, UDOT is attempting to replace some of the targets closest to buildings with Gazex, in part to address these fragmentation concerns.

The mountains near Salt Lake City are used by a large number of people for backcountry skiing and snowboarding. UDOT recognized that increasing numbers of backcountry users corresponds to increased risk of someone entering closed terrain during the time avalanche control work is scheduled to occur. This risk contributes to the direction of moving away from dependence on artillery.

In recent years the costs of obtaining military artillery and of maintaining an artillery program have risen sharply, which made seeking alternative methods for control work a more appealing choice.

In 2006 the Little Cottonwood Canyon SR 210 Transportation Study identified Gazex as a possible alternative to military artillery. In an attempt to address the concerns outlined above, UDOT chose to begin its Gazex program in the terrain across from the Snowbird Village. In 2007 two exploders were built as a test of the product and technology for the highway avalanche-safety program. After four seasons, UDOT decided to expand the Gazex program and in 2011 purchased seven more exploders at a cost of $507,000. In 2012 UDOT awarded a contract to Doppelmayr USA, Inc., to install two of the exploders for $237,000 during that summer.

Doppelmayr USA, Inc., employees works on one of the two new Gazex installations.

The new exploders replaced two of the targets that are closest to buildings. They were operational in November of 2012. Currently, UDOT has four Gazex installations and 145 remaining artillery target locations. Planning continues for the installation of the rest of the Gazex exploders in the summer of 2013.

Chris Covington works as an avalanche forecaster for the Utah Department of Transportation. He also dabbles as a ski patroller at Snowbird.

right: The CAIC Benefit Bash gets bigger and bigger every year, attracting more people and raising more money for the CAIC.
Photo by Brandon Doza

Coloradans Enjoy CAIC Benefit Bash

Story by Aaron Carlson

Coloradans love a party that includes beer, food, and free swag. But we also really love a party that is for a good cause. The 5th Annual CAIC Benefit Bash hosted in November was another one of these great parties that combines both attributes.

While the winter of 2011/12 left us with memories of sadness, poor snowpack, and a bike season that began in March, the Friends of CAIC were planning this party as the start to a better winter. The party kicked off fundraising efforts for the Colorado Avalanche Information Center and supporting avalanche forecasting and education throughout the state of Colorado.

The Benefit Bash is an opportunity to bring people together for a cause we all believe in. In the past five years, the CAIC Benefit Bash has grown exponentially in terms of the amount of money raised, the number of sponsors on board, and the amount of people we pack into the Breckenridge Riverwalk Center. The first year we hosted this party, we raised $26,000 and hosted about 700 people. This year we raised $82,318 and most likely broke fire code with nearly 1500 attendees.

The Friends of CAIC and directors Aaron Carlson and Joe Vandal are proud to have created an event in Colorado that people look forward to each season. We have to thank the army of people behind us who support the Benefit Bash and the people who really make it successful. First, our presenting sponsors: Backcountry Access, Vail Resorts, Voile USA, Weston Snowboards, and New Belgium Brewery. Second, we have to thank Vanessa Agee and the Town of Breckenridge, and Jen Cawley of Storm Restaurants. Vanessa and Jen have been absolutely vital to the success of this event and have been supporting us since year one. Third, the 130+ sponsors of the Friends of CAIC. Each and every one of these sponsors believes in what we are doing and understands the importance of the avalanche center. Last season was terrible for the ski industry, and we didn't know what to expect when we were reaching out to our sponsors. The immense support we received is absolutely mind blowing. Fourth, the 55 volunteers who actually run the show. To put on an event like the Benefit Bash we have to have an incredible amount of volunteers. We can do all the planning in the world but without trustworthy volunteers the event would be a complete mess. Last but of course not least, the attendees. These are the folks buying tickets, walking through the door, and really making the event such a wonderful success. Each year, we are completely amazed by the number of people who are just stoked to be there, whether or not they win a thing.

Aaron Carlson is the executive director of the Friends of CAIC.

Kirk Bachman (at left) poses with Sara and Chris Lundy in front of the Williams Peak Hut at the end of a recent L1 course.

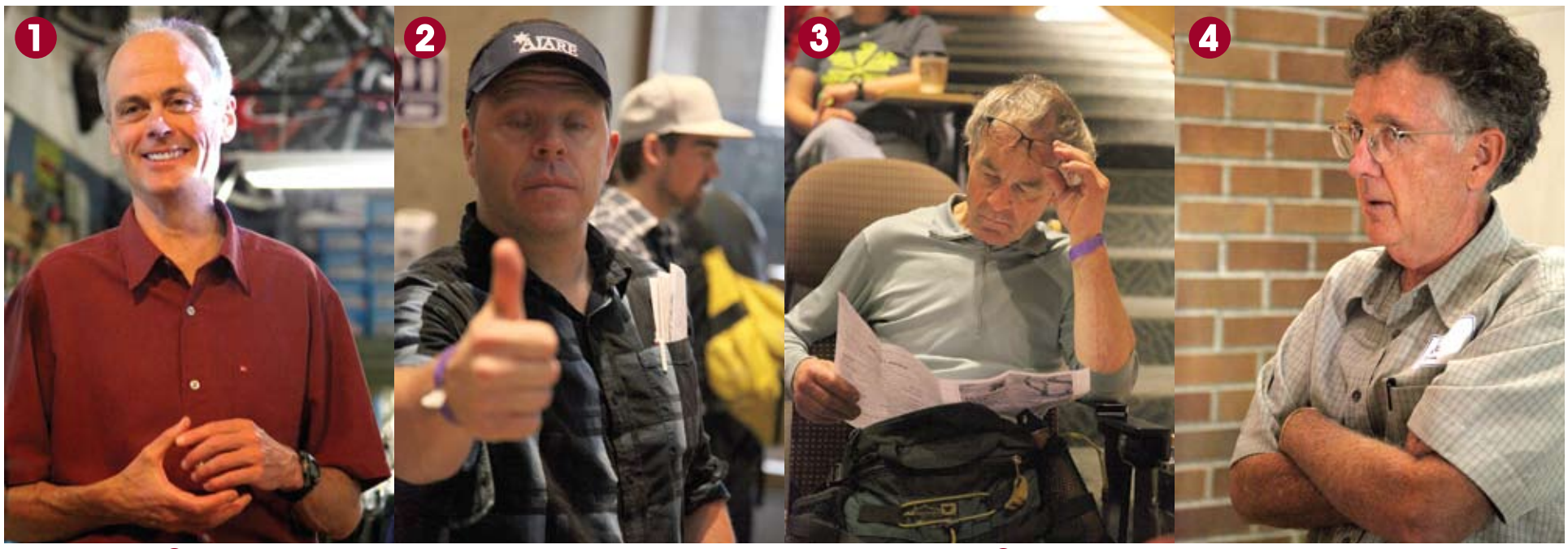
Sawtooth Mountain Guides Announces New Owners

Sawtooth Mountain Guides is excited to announce that as of January 1, Chris and Sara Lundy have become new co-owners of the company, purchasing half ownership from SMG founder and long-time owner/operator Kirk Bachman.

Stanley residents Chris and Sara bring a wealth of experience and expertise to SMG. Sara began working with SMG in 2001 and has been a ski guide in the Wood River and Sawtooth Valleys for 10 years. She is one exam away from being an AMGA-certified ski mountaineering guide. Chris holds an MS in snow science and worked as an avalanche forecaster with the Sawtooth National Forest Avalanche Center for the past eight winters, becoming the director in 2010. He is also an accomplished ski mountaineer.

Kirk began working as a mountain and ski guide during the mid-'70s in the Sawtooths and Tetons. Eventually his tendencies began leaning in favor of the Sawtooths, and he founded Sawtooth Mountain Guides in 1985. He first introduced the Mongolian yurt as a backcountry shelter to the mountains of North America – the Williams Peak Hut – and constructed the first "yurt hut system" in the Sawtooths. Kirk will continue to be involved with SMG as an avalanche educator, guide, and valued advisor.

Read Kirk's thoughts on the transition at sawtoothguides.com/2013/01/03/transitions-at-smg/



Faces of the NSAS: ❶ Garth Ferber, forecaster at the NWAC, revels in the outpouring of support for his forecast center. ❷ From Steve Christie of BCA: "A grad student at UW in Seattle was showing us how to measure slope angle with just half of a thumbnail. It didn't work for me – not even close!" ❸ Chester Marler, long-time Pacific Northwest ski adventurer, takes a moment to study the event program. ❹ Tom Murphy of AIARE makes a yearly pilgrimage to NSAS. This year he discussed how a communication checklist can help prevent accident formation.

Northwest Snow and Avalanche Summit

Story by Joanne Standford • Photos by John Stimberis

The fifth annual Northwest Snow and Avalanche Summit was held on November 4 at Kane Hall on the campus of the University of Washington in Seattle. Just over 300 people spent the day expanding their knowledge of snow, avalanches, meteorology, and heli operations. Risk and its management provided the topics of the day.

Event sponsors included the American Avalanche Association, REI, American Institute for Avalanche Research and Education (AIARE), Friends of the Northwest Avalanche Center, Backcountry Access, New Belgium Brewing, David Pettigrew Memorial Foundation, Alpental BARK, Cascade Powder Cats, Summit Ski Area, K2 Sports, PowderWhore Productions, and The Mountaineers.

(l-r): Rich Marriott, KING TV meteorologist, poses with co-conspirators The Wiener (of ISSW fame) and Mark Moore.

The day started with Mark Moore, the soon-to-be-retired director of the Northwest Weather and Avalanche Center (NWAC) who will be missed by all of the forecasters he has mentored over the years *(see feature on Mark and his remarkable career starting on the next page)*. Mark relayed some insight into managing the risk we all face while traveling in the backcountry. He also took the group on a short tour of some changes happening within NWAC concerning the way they relay information to the users. Of course, in keeping with his creativity, he had a poem to share:

Side country, slack country – these terms are hot.
But the risk here is assured, and your safety is not.
Avalanches and SIS are part of the risk.*
No control nor patrol, in case that was missed.
Rescue's expensive, and may not happen at all.
But the gate is open, so it is your call.
Just know that your safety is all up to you.
And how, when and where, you choose what you do.

Paul Butler, co-owner of North Cascade Heli, gave am inside look into the operation of a heli-guide business and the steps his forecasters take to evaluate the day's hazard, and in turn make terrain decisions. He also touched on dealing with last winter's snow conditions and the affect they had on his operations.

Dr Michael Medler had the group smiling with his humorous look into the work he and his students are doing with GIS mapping of the danger rose published by NWAC. Yes, he made maps funny! Michael discussed the benefits and the potential problems of mapping avalanche hazard in this form, which can take mountain terrain down to pixels.

John Stimberis from WSDOT talked about the risk to the traveling public on the highway and some of the problems his forecasters encounter keeping up to 45,000 cars and trucks per day safe from avalanches. John also gave us a glimpse into the complexities of designing highways that travel through avalanche country and the pros and cons of snow sheds versus bridges.

Tom Murphy of AIARE encouraged us to be lifelong learners. He discussed managing our risk by making good, well-informed decisions. Tom handed out small cards with the AIARE communication checklist, outlining four topics with a few simple questions to help us identify potential problems and have a safer trip.

One of the most moving presentations was given by Marcus Engley and Roger Strong. The pair talked about their accident last winter on Snoqualmie Mountain that left Roger with two broken legs and the whole group injured in some way. As the men told their story, it was clear that this accident held some of the classic heuristic ingredients for disaster: lack of communication between group members for a variety of reasons, time pressure, and familiarity with the area.

Larry Schick ended the day by giving us some pointers on where to look for good weather and snow information. In addition to his Web site, "Larry Schick Powder Alert," he recommended NWAC, National Weather Service, and the simplist of all – just take a peek at ski area and DOT cameras to see current weather!

By late afternoon, everyone was ready for a cold beer and some smoked salmon provided by our host Michal Jackson.

Stevens Pass Pro Patroller, Liz Stone was an NSAS first timer. She was impressed with the depth of knowledge provided at a great price. She is going to encourage her friends and co-workers to attend next year, saying it's a great way to start thinking about winter and being safe in the mountains. For more information about NSAS, please contact Michael at powderhino@aol.com.

Joanne Standford is a long-time Northwest avalanche worker who is now happily retired, giving her the opportunity to donate her time to worthy events and causes like the NSAS.

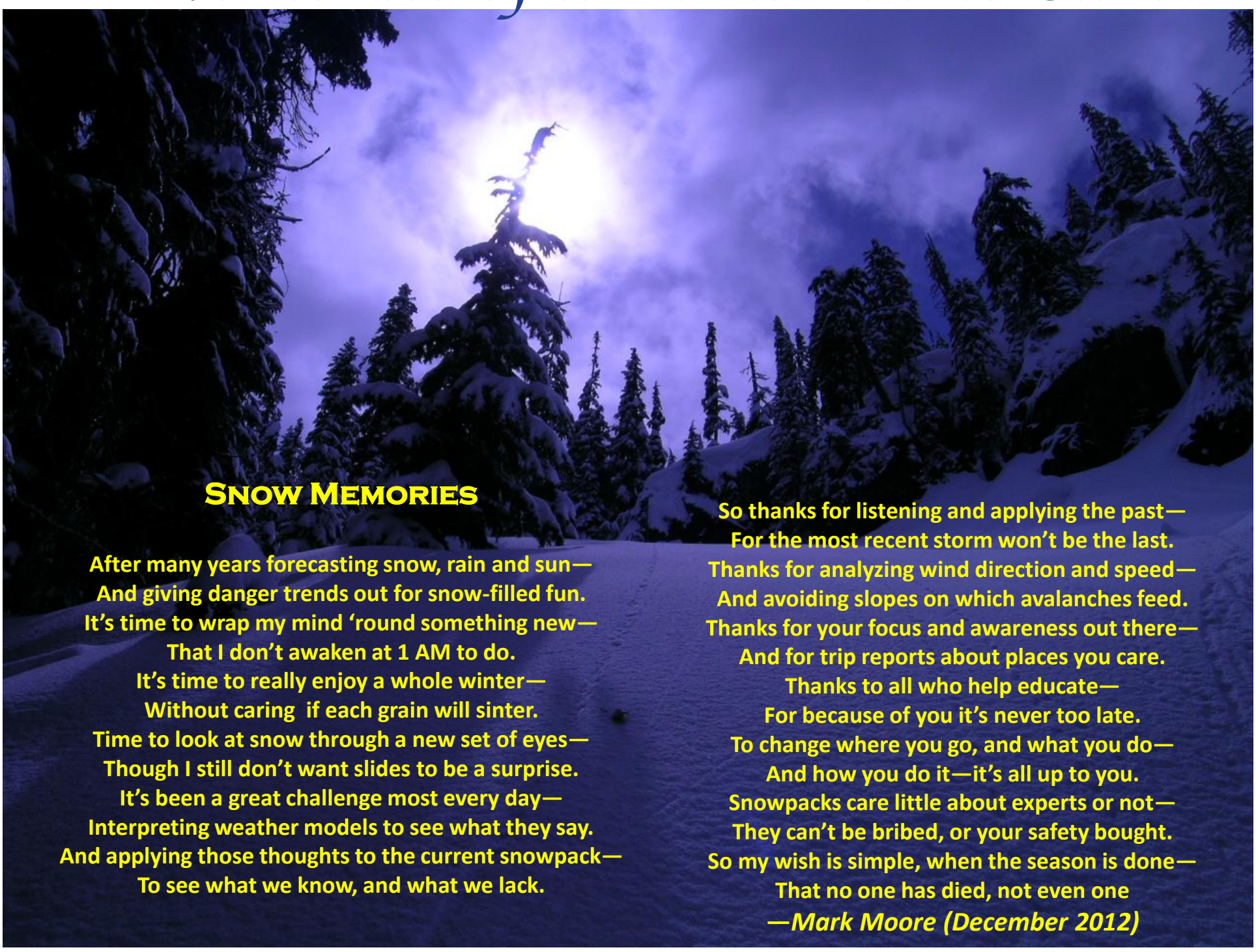
In the classic "Wires of Mystery" skit, Kenny Kramer and Garth Ferber spoof Mark Moore's fascination with the complexities of weather station wiring.

The NSAS organizers gave a wooden plaque to the AAA as a token of appreciation for their support since the inception of the event. Here (l-r), AAA board members Brad Sawtell (CI rep), Patty Morrison (NW rep), and John Stimberis (vice president) accept the award on behalf of the AAA.

crown profiles

Mark Moore Retires:

Memories of a Remarkable Career



Snow Memories

After many years forecasting snow, rain and sun—
And giving danger trends out for snow-filled fun.
It's time to wrap my mind 'round something new—
That I don't awaken at 1 AM to do.
It's time to really enjoy a whole winter—
Without caring if each grain will sinter.
Time to look at snow through a new set of eyes—
Though I still don't want slides to be a surprise.
It's been a great challenge most every day—
Interpreting weather models to see what they say.
And applying those thoughts to the current snowpack—
To see what we know, and what we lack.

So thanks for listening and applying the past—
For the most recent storm won't be the last.
Thanks for analyzing wind direction and speed—
And avoiding slopes on which avalanches feed.
Thanks for your focus and awareness out there—
And for trip reports about places you care.
Thanks to all who help educate—
For because of you it's never too late.
To change where you go, and what you do—
And how you do it—it's all up to you.
Snowpacks care little about experts or not—
They can't be bribed, or your safety bought.
So my wish is simple, when the season is done—
That no one has died, not even one

—Mark Moore (December 2012)

above: Mark Moore's final forecast, December 26, 2012

Through his friendship with Sue Ferguson, the founder, Mark has always been a supporter of *The Avalanche Review*.

Photo courtesy Roland Emetaz

The man behind the camera lens.

Photo courtesy Craig Sterbenz

Honoring Mark Moore, in 10 Lines or Less

Story by Roland Emetaz, aka Mr Em

I first met Mark at the end of the 1977/78 winter season, at a meeting where the University of Washington handed off the completion of a research program funded by the Washington Department of Transportation. It was called the Central Avalanche Hazard Forecasting Project.

Mark and Rich Marriott were then students of Ed LaChapelle, and under Ed's guidance they developed the methodologies for evaluating snowpack stability at a central office using meteorological and snowpack observations to produce mountain weather and avalanche forecasts. The meeting, involving a number of state and federal agencies, was to determine the next step. All were supportive and willing to cooperate, but no one wanted to take the lead. In the end it was determined that the Forest Service should be the lead agency; I was there representing the Forest Service, and the rest is history.

I essentially supervised the program and Mark, et al., until the mid-1980s. Though I really did not supervise Mark (does anyone?), just nudged the rudder occasionally.

For me the relationships with Mark and the program were very rewarding. The program produces a valuable product both in terms of people's safety and in terms of cost savings for cooperators (e.g., scheduling of personnel and activities, decreased SAR missions, etc.). As far as our relationship as friends, I was always close with Mark and Ginger.

The following is what I wrote to people in advance of the recognition event for Mark's retirement:

Hello Mark's Friends,

In connection with the Northwest Snow & Avalanche Summit's Social, we are planning on recognizing Mark's many years of service, providing mountain weather, avalanche forecasting and avalanche education to the community.

The event will be held at Second Ascent/SEA.

We realize that many of you are from afar and will not be able to attend, but may be willing to write a short limerick, 10 lines or less. We will read or post them at the event. So here is an example written by Rich Marriott:

There was a young man from Bothell
Who thought unstable snow was awful
He said, "I know a way
To know when to play,"
Because his forecasting skills were colossal

Best Wishes For The New Year!

Roland Emetaz, aka Mr Em, has enjoyed a remarkable friendship and partnership with both Mark Moore and the NWAC over the years. He's a long-time supporter of avalanche education and the NWAC, and championed the formation of NWAC back in the early days. The Avalanche Review *is honored to be Mr Em's preferred reading even at the beach.* ❄

A Remarkable Career

continued next page ➡

A Remarkable Career

continued from previous page

Notes on a Friendship

Story by Craig Sterbenz

Well, let me see, waaay back in 1966 I moved into a small "suite style" dorm building on campus at the University of California, San Diego. There was a cluster of a half dozen of these smallish dorm buildings that were designed to create a sort of community atmosphere. They were all named after some famous oceanographer's or explorer's ship. I was in Beagle Hall, named after Charles Darwin's ship. As a freshman there to study oceanography, that seemed pretty cool. That's where I met Mark. I think that he lived in the building next door, maybe Meteor Hall? He was a year my senior and well on his way to a successful career as an aerospace mechanical engineer. I suppose I'm at least partially responsible for for him straying from that lofty goal.

Not only was I a freshman at school, I was a neophyte on skis. Mark was not only a sophomore, he was a master on skis. He was an "army brat" and learned to ski as a youngster when his dad was stationed in Garmisch, Germany. Mark's dad patrolled at Mammoth during the winters while Mark's mom stayed at their home in the Southern California desert. She hated being in the snow. Mark's dad was one of the most fluid skiers that I had, or have to this date, ever seen. I had just been introduced to skiing a couple of years earlier during high school, and I really had the bug to learn. I wanted to learn to ski like Mark's dad. Literally, I had "The Bug." I was the proud owner of a flashy anthracite-grey 1964 VW Bug with a ski rack on the back, and I was desperate to learn to ski. Mark knew the "Christie" and could "wedeln," but he had no wheels. A friendship was born.

We would load up the VW and make the long drive from San Diego to Mammoth just for the weekend. In those days gas was only 23 cents per gallon. We could fill up the VW for $2.30, so it didn't cost us much to get there and back. Mark knew all the ropes. His dad was working as a ski patrolman at Mammoth, so we slept on his dad's floor and for an hour or two of "work" at the mountain we could get a free ticket. The biggest cost was probably to our studies when some of those two-day weekends were stretched to four or more.

One spring Mark got us set up with a "job" for room and board at the Alta Peruvian Lodge for spring break. We ate with the guests at the lodge, skied deep powder all day, addressed newsletters for an hour or so at night, and left with enough money to pay for the gas home. When I say "we" skied deep powder all day, I mean Mark skied it, beautifully, and I wallowed in it. Remember, I was only a neophyte and he the master. He was a very patient instructor, and I am eternally grateful he didn't let me suffocate in one of those tree wells.

Over the next couple of years we formed the UCSD ski club and set up a network with other "ski clubs" at colleges throughout southern California. This network became the Southern California Inter-Collegiate Ski Racing Association. This allowed us to spend more time in the car together traveling to and from the mountains to ski, but now we were sponsored by the University. We had a big gas-guzzling American station wagon that came with a credit card complete with Ronald Reagan's name on it. He was only the Governor (and head of the University's regents) in those days, but it sure was fun when we signed his name at the gas station. Mark and I spent a lot of hours together on the road. From Alta to Aspen to Mammoth and Squaw Valley, we shared and developed a lasting friendship…

During my senior year at UCSD Mark had graduated and was living and working full time on ski patrol at Mammoth. I continued my weekend trips to Mammoth, now getting to sleep in Mark's extra bed rather than on his dad's floor. I do recall a few good girlfriend stories from this time period but will leave the rest to our memories and your imagination. When Mark started working on patrol at Mammoth he was given a skinny locker. His name didn't quite fit on the front so it was abbreviated as MaMoo. That became his nickname on patrol and thereafter.

When I graduated from UCSD in the spring of 1970 we moved to Aspen and became roommates. Our plan was to work there for the summer, earn a few dollars and head to Europe for the following winter… It was there in Aspen that he met his "Ginger." Mark was fascinated by the spicy young pianist from New York who was there for the Aspen Music School. When she left for California School of the Arts that fall, Mark had to follow.

I stayed on in Aspen and started ski patrolling at Aspen Highlands while Mark was biding his time in southern California. His love, Ginger, was there in the so. cal. desert, but part of his heart remained in the snow. As soon as Ginger finished music school there, they moved to Seattle, and Mark started his new career as a student in the department of atmospheric sciences at the University of Washington. It was there that Mark met Ed LaChapelle, Sue Ferguson, Pam Spears, and Rich Marriott. Together they started the NWAFC, sowed the seeds of what is now ISSW, and gave life to *The Avalanche Review*.

Thanks MaMoo, sterbie

Sterbie is currently Patrol Director at Telluride Ski Resort and former ethics chair on the AAA Governing Board.

Craig Sterbenz and Mark share a story. I bet there are a lot more stories than the ones that Sterbie shared in the story at left. *Photo courtesy Craig Sterbenz*

There once was a guy named Mark Moore
Who convinced his wife it was OK to be poor
He said, "I'll study snow,
And watch the wind blow,
And try to predict when the rain will pour."

So farewell to our good friend Mark
Enjoy some time at the park
Enjoy your free time
Make up a few rhymes
We'll surely miss your input and spark!

Mark, best wishes! You have been a great contributor to our community for so many years and we will really miss you. Have a great retirement and be sure to keep in touch!
Karl Birkeland

In some ways nothing has changed: Mark and Sterbie were roomies in 1970 in Castle Creek, Aspen, Colorado. *Photos courtesy Craig Sterbenz*

Mark and I met up in the fall of 1975 at the University of Washington – working on the "Central Avalanche Hazard Forecasting" project under Ed LaChapelle. Mark in his usual generous fashion was a kind and patient tutor teaching me to embrace heavy packs, digging 20' deep snowpits, and laying miles of power and telemetry cable. We worked together for 15 years and had uncountable adventures – fortunately the authorities never quite caught up with us! After I left the Avalanche Center, Mark continued to fight the battles, and he has succeeded in making the NW Avalanche Center the invaluable resource it is today.
Rich Marriott

Mark (Mamoo) Moore wedelning in style, circa 1968, for the UCSD ski team that he and Sterbie organized in college to help legitimize their ski addiction.
Photo by Craig Sterbenz

I will not be able to attend and I'm horrid at limericks so here is a quick story about Mark Moore, someone I have always liked and admired very much.

I have always been envious of those who were able to be part of the Northwest Avalanche Center back in those early, heady days — Mark Moore, Rich Marriott, Sue Ferguson and, of course the grand wizard himself, Ed LaChapelle. I was especially envious at the first of the two Squaw Valley ISSWs in 1986, if memory serves. One night I was out partying with Mark, Rich, and Sue and they were doing their usual comedy improv — training for a career in stand-up comedy, I figured, in case the avalanche thing didn't work out. It was like being in a room with Robin Williams in the early days, but times three. The next day my stomach and face ached from laughing so hard, which went on for hours, as usual. I feel lucky to have witnessed so many episodes of comic genius through the subsequent years working with Mark at various avalanche schools, committee meetings, and avalanche conferences. So old friend, is it finally time for your next career?

Bruce Tremper

Mark with Sue Ferguson and several bottles of her specially bottled TAR wine, a few of which Rich Marriott was able to save for the Avalanche Divas at the ISSW this fall. *Photo by Craig Sterbenz*

Just tell Mark,
I sure appreciate the help he gave me a few years back.
He's a true avalanche friend.
We can use a lot Moore like him.
Ron Perla

Kenny Kramer and Mark Moore of the NWAC, in a casual moment.
Photo by Garth Ferber, the third in their long-time forecasting trinity

Do you know this fellow Mark Moore?
Who's unlike anyone you've met before?
Brilliant and crazy – and so far from lazy
And his orations never will bore

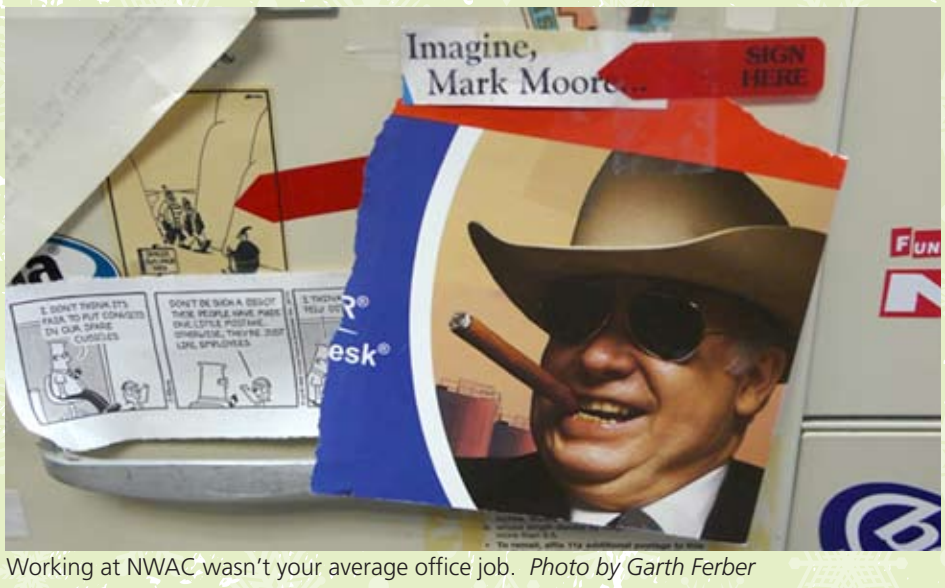
Now casting about in the '70s
Mark asked "what job might suit my proclivities?"
Snow, brains and skiing – investing his whole being
Four decades of surmounting all difficulties

Needing comrades to share in the work
Mark sought folks he'd not drive berserk
Rich, Pam, and Sue – then Garth and Kenny too
Was Mark's passion more a pain or a perk?

As the snows start to fall in the passes
And fresh forecasts dispensed to the masses
With a forecast of "sunny again" – why are we skiing in the rain?
Are forecasters wise wizards or pains in the asses?

Though his recreations weren't always pure
(remember "Black Magic"?)
He's worked long and hard – for sure
With grit, heart, and drive – he's built a center that thrives
And beyond him will grow and endure
With grit, heart, and drive – he's built a center that thrives
And beyond him will grow and endure

Pam Speers-Hayes and Peter Hayes



Working at NWAC wasn't your average office job. *Photo by Garth Ferber*

A Remarkable Career
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High Arctic Maritime Svalbard

Introducing a new snow and avalanche climate

Story by Markus Eckerstorfer and Wesley Farnsworth

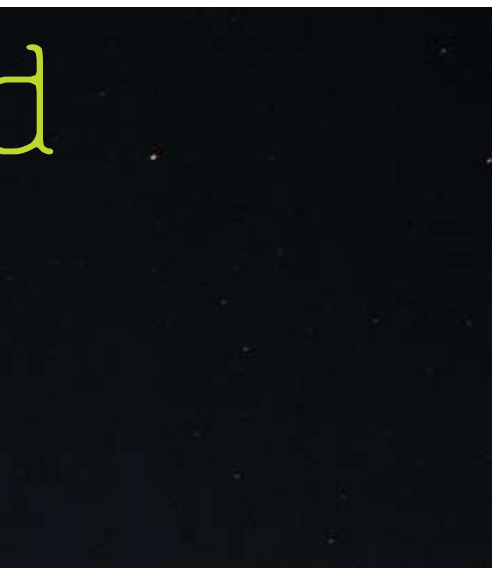
Scenes from Svalbard

1 An open cornice tension crack, detaching the entire cornice mass from the snowpack on the plateau. The cornice can then creep freely downward until it tips over.
photo by Ulli Neumann

2 Avalanche activity monitoring along the 70km most-used snowmobile route around Longyearbyen, Svalbard's main settlement. All observations were done in accordance with SWAG guidelines.
photo by Ulli Neumann

3 Debris of a D3 slush avalanche that released in an extreme wet avalanche cycle on March 18, 2011. Note snowmobile and rider *(circled)* for scale. Note the truncated flow arms, indicating a differential flow regime and a release in surges.
photo by Markus Eckerstorfer

4 A large, D3 cornice-fall avalanche. We often observed entire cornices in the debris, as large as family cars.
photo by Ulli Neumann



Snowpack observation during the Polar Night. Svalbard experiences complete darkness from the beginning of December until end of January.

photo by Stephan Vogel

The Svalbard archipelago is a small group of islands at 80° North in the Norwegian High Arctic. The first explorers in the 16th century gave the main island the name Spitsbergen, which means "pointed mountains." With a snow cover lasting for up to 10 months a year at lower grounds, Svalbard is a skier's paradise and an archipelago full of avalanche terrain.

However, only in recent years, Svalbard appeared on the map of a number of large ski movie production companies such as Teton Gravity Research and Warren Miller, presenting its endless potential to the ski world. Tight couloirs, flat runouts, jagged peaks, the endless midnight sun, fjords in the distance, and the lurking polar bear threat make Svalbard a unique ski adventure.

In recent years, increasing numbers of winter backcountry enthusiasts are visiting Svalbard and with that, the number of avalanche accidents and fatalities will potentially rise as well. We therefore initiated the first avalanche research project at the University Centre in Svalbard, located in the main settlement, Longyearbyen. Beginning in 2006, the goal was to monitor avalanche activity in the most used areas around Longyearbyen and research avalanche cycles, type distribution, topographical parameters, and meteorological triggers. This information should then lead to a first quantification of the snow and avalanche climate of central Svalbard, then potentially leading to an avalanche warning and forecasting service. This type of program would be timely and important as five people have died in avalanches since 2000; all were self-triggered by snowmobiles.

When we started with the research project, we expected the snow and avalanche climate to not be significantly different from other alpine areas. However, we hypothesized that the avalanche activity timing would be largely determined by the extreme light conditions due to complete darkness during the Polar Night and 24 hours of sunlight during the Midnight Sun period. After driving a 70km-long snowmobile route up to three times a week for four winter seasons, we could finally quantify our hypothesis. Fieldwork proved that there was minimal activity during the Polar Night, with the majority of releases occurring quite late in the season, between April and June. This is due to a generally thin (only 200mm SWE annual precipitation at sea level) and very slow onset of continuous snow cover throughout the region with maximum depths seen in April. Investigations also indicated the absence of loose snow avalanches during the Polar Night and the dominance of cornice-fall avalanches, which were generally triggered late in the season at their maximum extent.

The dominance of cornice-fall avalanches is unique to central Svalbard due to the large plateau mountains in the area, the scarcity of any high vegetation, and a constant prevailing winter wind direction. As almost half of all avalanches we observed were cornice falls, we stuck our heads further into the mechanisms of cornice formation, evolution, and failure. We know now that it only takes one snowstorm to fully accrete a cornice at its maximum vertical size filling the nivation niches on the plateau edge. As the season develops the volume stays relatively constant, but mass is added as the snow settles and deforms under its own weight. It only grows horizontally outward from the plateau and slowly creeps downslope.

Lots of work on cornices was previously done by the famous John Montagne on the Bridger Ridge in Montana, and we could repeat and build upon his findings. One of them is the observation of cornice tension cracks, where due to the downslope creep of the cornice, a crack opens between the cornice mass and the snowpack on the plateau. We found this to be a prerequisite for large cornice failures, sometime forming up to three to five weeks prior to failure (in addition to sometimes never failing and just melting out). However, we could not distinguish cornice-fall avalanche from non-avalanche days based on meteorological factors.

Thirty percent of all avalanches we observed were slab avalanches. These were typically smaller than the cornice-fall events and had an average starting zone inclination of 45°. The snowpack consists of a depth-hoar base and a high number of weak layers, mainly facet-crust sandwiches in the middle third of the snowpack. However, the upper hard wind slabs or meltform layers seem to bridge weaknesses quite well. As a result, we have not observed a single skier-triggered slab on depth hoar in the last years. Only snowmobilers were able to trigger full-depth slabs. This means that we also have not observed full-depth natural dry slides; the majority were direct-action slab avalanches, with failures in the new snow-old snow interface or the wind slab. Therefore, precipitation and snowdrift, 24, 48, and 72 hours prior to a slab avalanche

day were the best predictors for release.

The observing reader may have noticed that parts of the snowpack are comprised of meltforms and crusts. This is not unusual for the snowpack in Svalbard; it's rather typical. Precipitation events are mainly due to passing low-pressure systems, resulting for the most part in snowstorms. When these low pressures pass, air temperatures can suddenly rise from -20°C to slightly below freezing within hours, accompanied by snow and wind. This means that powder days are rather rare in Svalbard and a little dust on crust is what we call a "sick day." However, the snow sticks well to the steeps and, in combination with the hard bridging meltform layers, makes for probably safer-than-average skiing conditions.

Slowly passing low-pressure systems also result in mid-winter rain-on-snow events, which often cause extreme mid-winter wet slab and slush avalanche events. These wet avalanches were extreme in number of releases within one cycle, debris volume, and runout length. Some wet slides were quantified as D4s. Such wet avalanche cycles are thus a characteristic of the maritime influenced snow and avalanche climate of High Arctic Svalbard. However, when analyzing the almost 100-year-long meteorological record from Svalbard, we could not find a relationship between rising annual air temperatures and frequency of mid-winter rain-on-snow events. Rather the frequency and intensity of low-pressure passages seems to be the determining factor.

This is the state of basic knowledge we have gathered so far, forming the foundation for future avalanche program in Longyearbyen. As avalanche forecasting was just initiated in mainland Norway last year, there is still plenty to stay busy with: determining how to collect data, educating observers, putting necessary observation infrastructure in place, and making the public aware of the hazard. We recently applied for a workshop grant to gather avalanche scientists and practioners in Svalbard in spring 2013, which will help us take one step further toward our goals.

Markus Eckerstorfer is an Austrian-born snow researcher and enthusiast. After spending a season at the Tyrolean Avalanche Service he moved up to Spitsbergen. In 2008 he began a PhD program on the meteorological control on snow avalanches in Svalbard through the University Centre in Svalbard. Max is a dedicated backcountry skier and an AIARE Level II holder.

Wesley Farnsworth was born in Maine and raised in Vermont. Upon finishing his undergraduate studies at Bates College in geology and Spanish he moved to Svalbard to pursue a master's degree in the spatial variability of snowpack across wind-effected terrain. Wes is an avid outdoor recreationist and an AIARE Level II holder.

A Remarkable Career

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Weather Geek Memories

Story by John Stimberis

When I was about nine or 10 I got up at six every morning for several months to record the air temperature. It was probably for a school assignment or Cub Scout badge, can't really recall. What I do remember is the fascination I had with recording the temperature. Would it be warmer today or colder? What's the warmest or coldest it could be? At some point I ended the project, but I was still enthralled by the weather.

Flash forward many years and I still record the temperature at 6am, along with many other bits of information about the weather and snowpack. Nowadays on these cold and dark mornings I often ask myself what I'm doing. But really, what was I doing as a young boy? Those thoughts fade, and I think about where these endeavors have led me in life. Beyond working with snow and weather information I've had the opportunity to work with some interesting people over the years. One person I've been very fortunate to work with and learn from is Mark Moore. You know Mark, director and founder of the Northwest Weather and Avalanche Center, poet, and general funny guy.

I first met Mark in a lift shack at Alpental. I was a new patroller, eager to learn about the snow and avalanches, and the weather no doubt. In walks this guy who begins to open the electrical boxes and fiddle with a mess of wires. I inquired what he was doing and he told me he was working on some of the weather instruments and the telemetry. I was curious and somewhat excited. There's more to the weather than what is outside – there are instruments, and telemetry, and wires. A whole mess of wires; it looked mysterious. I asked some questions, and Mark gladly answered. I had no idea what he was talking about, but I wanted to know. I guess that's the first step to learning.

Over the years at Alpental I got to know Mark and the NWAC guys a bit. I tried to assist or at least tag along when they, or Rob Gibson, then with WSDOT, would come to Alpental to work on the instruments. My real experiences with Mark didn't get going until I started with the WSDOT. I then had the opportunity to work with the NWAC crew on a regular basis: calling for weather information and providing snow and avalanche observations, and slowly learning more about data loggers, instruments, and data flow. I also had to learn a personal form of shorthand that is an absolute must if you are receiving a weather forecast from Mark. My fellow Northwest avalanche folks know what I'm talking about.

I must have showed some promise during those formative years, and I was invited to join a Campbell Scientific, Inc., course hosted by Sue Ferguson, distinguished NWAC alum. As I slowly got a feel for instrumentation and such, I was given more opportunity to troubleshoot and repair stations. I delved deeper into the mysterious wiring boxes that I had seen in my early days of patrolling and working around the ski area.

Around that time I discovered the Holy Grail; a box within a box. Wires led everywhere, many no place at all. Someone had written a message on the inner box, likely in a last ditch attempt to salvage their own sanity and hopefully warn a future generation about the perils within: "The Wires of Mystery," scrawled in black Sharpie. I pushed my way past a rainbow of wires, looking something like a unicorn's dreadlock unraveled. There were more wires, black tape, film canisters with wires attached, and notes scribbled about obscure connections. All of this for a station that only records temperatures? No, there was an upper station that routed through this site as well. Nobody knew how many splices, junctions, and fuses the weather data travelled through. Well, one person did: Mark Moore.

When I asked about the station he spoke of resistors and resistance, ohms, volts, voltage drop, capacitors, transformers. It was all so confusing. Slowly, though, some of Mark's lessons have worn off on me. I understand some of the basic concepts of weather, and I feel somewhat capable of troubleshooting and repairing a weather station. I've learned to program dataloggers, even when they involve complicated math such as Mark's infamous fifth order polynomial (I just copy and paste the equation).

Mark has taught me quite a bit over the years, and he's really been a great mentor to my career. I only hope my efforts show how much his guidance has provided. Thank you Mark, and may you never have to answer the question, "When is the snow going to turn to rain," again.

John Stimberis is now creating his own "Wires of Mystery" weather stations for future generations to unravel as an avalanche technician at WSDOT. He is also vice-president of the AAA Governing Board and a prolific and talented photographer.

What's the plan, Mark? No telling... *Photo by John Stimberis*

What can we say about this photo? TAR and the Wiener...the best reads the best.
Photo by John Stimberis

A fine forecaster who was named Mark,
Sparked NWAC up, just for a lark!
But ski/riders soon knew,
Of his accuracy true,
Helping know when to Go Big, or Park!

Laura Green from Mt. Hood

This will be quite an event – and I'm honored to have known Mark and gained from his wit and wisdom. Please give him my regards and sincere thanks for all his years of service.
Regards, Don Bachman

As the weather covers the mountains in snow
Backcountry skiers will want to know
Where has Mark Moore gone
For his forecasts they will long
Because a skiing they want to go

Dave Wagg, editor of *Off-Piste Magazine*

At the 1982 ISSW in Bozeman, MT, during the Ed's Demon Drums Tour to ISSW and Yellowstone!
Front row (kneeling, l-r): Rich Marriott, unidentified dog & ball, Ed LaChapelle.
Back row (standing l-r): Cindy Marriott, Richard Armstrong, Paul Baugher, Pam Speers-Hayes, unidentified child, Betsy Armstrong.
Top of van (l-r): Mark Moore, Sue Ferguson. *Photo courtesy Garth Ferber*

Rich Marriott tells TAR: This was the first appearance of the Wiener at ISSW. I had "purchased" him for $10 out of involuntary servitude at a Bingo Gas Station in Thorpe, Washington, on the trip to Bozeman.

Hello Mr EM,

So far my lyrical skills are escaping me, but I wanted to share a couple of my favorite memories of working in the field with Mark. The first of which (the first two pictures) was the the Frostfire experiment up outside of Fairbanks in I think it was 1999. Our purpose was to set up a bunch of weather stations and other smoke measuring instruments around a prescribed burn and also run a tethersonde up and down through the drainage of the valley all night to measure weather conditions (wind, stability, etc) and how much smoke the fire was putting as it smoldered through the moss and duff. Of course the best place to set up to capture maximum drainage flow was right at the low point at bottom of the valley. This was my first introduction to precisely how cold (especially when cooling is aided by permafrost) and smoky nighttime inversions can get on fires (a valuable lesson later) and also the birth place of Wally the Sky Pirate (Walrus). I can't remember if Wally was Sue or Mark's inspiration, but he did certainly end up a great joint creative effort.

The next was a summer or two later working up in the Baker City Watershed in Oregon. In this case we were setting up weather stations again but also scouting out a potential site for an infrared camera…hence a long adventure in the Forest Service Suburban up an "interesting" rocky road system, some of which were substantially smaller than the Suburban. This was particularly fun for me because I got to drive (and I do really appreciate Mark's patience and trust to let me do that given the roads)…and as it turned out, it was the first of many, many trips later on for me out on fires looking for the best view points to observe the fires and weather.

I could mention many more, but those are two of my favorite memories. I really wish I could be there for the party. Thank you so much Mark for the fun times in the field, what you taught me about troubleshooting weather stations and radios (especially the importance of the position of the on/off switch) and most especially for helping to instill in me the love of working outside where you can actually see the weather. Best wishes, and hope to see you next time I am up in Seattle!

Julia Rutherford

Julia Ruthford is a National Weather Service forecaster on the East Coast now. She worked with Blue Sky Rains, a smoke trajectory model that Sue Ferguson developed.

The Moore clan: Jon, Ginger, Mamoo, Scoobie Doo, and Katie Too.
Photo by Craig Sterbenz

Hi Roland: We're glad you are doing this. It's on our radar and we'll try to come up with something. But at the moment, we're at sea, approaching the NE corner of South America, and a bit sleep deprived. More soon I hope.

Cheers, Jill Fredston

Trouble runs in twos (plus the one behind the camera): Rich Marriott and Mamoo at Paul Baugher's birthday party. *Photo by Craig Sterbenz*

metamorphism

continued from page 4

Congratulations

Congratulations to **John Fitzgerald** of Victor, Idaho, on being hired as the newest forecaster at the Chugach National Forest Avalanche Center.

l-r: John Fitzgerald, Kevin Wright, Jake Hutchinson, Wendy Wagner at Tincan parking lot, Turnagain Pass, AK. *Photo by Joe Stock*

A Survey of Ski Area Boundary Policies in the Pacific Northwest: Is Consistency the Answer?

Story & Photos by Dan Veenhuizen

So I'm standing there, watching it pile up on my skis. This day had been a great one, with 30cm since noon, and half of that in the past three hours. We had just closed the hiking route up Cowboy Ridge to out-of-bounds terrain. Normally the hiking routes stay open day and night, but when avalanche hazard becomes such that natural or human-triggered avalanches may affect our operational area, we close access from the ski area. My fellow patroller and I watched, incredulously, as two individuals skied up to the rope line we had just set up, took off their skis, ducked the rope, and started walking up. We were standing 50 feet away. I slid over to their tracks and followed them up. Their explanation was that at the area they normally visited (a different ski area in Washington), it was acceptable to duck ropes provided you had the required equipment and a partner. They had assumed the policy was the same here.

Stevens Pass signage.

The scenario described above has played out all over the Pacific Northwest. In a region with prodigious snowfall, wildly varied topography, and a population of users who like to access terrain via the chairlift, what is the best way to manage access to the backcountry from the lifts? This question has been answered in many different ways by ski areas in Oregon and Washington.

So, who cares? The aforementioned individuals who lost their tickets care. The casual skier who sustains trauma from an avalanche originating out-of-bounds cares. The bombardier who has to scrub a mission due to human life exposure cares. The avalanche professional at any given operation should care because their program most likely contains themes to be described herein. For the purposes of this essay, I will discuss the policies of six of the roughly 32 ski areas in Oregon and Washington. I will also briefly touch on the perspective of the Forest Service.

OREGON

Mt Hood Meadows (MHM)

According to the MHM Web site, backcountry access is not allowed from their ski area, period. The ski-area boundary is marked with rope lines and signage in its entirety. Violators face fines and loss of lift privileges. MHM meets many challenges to managing their boundary, which include an artillery program, the resort's physical location, and its proximity to a major population (Portland metro area).

Its location is a challenge because the area is situated high on the east side of Mt Hood, with the area boundaries adjacent to large avalanche paths. Would-be backcountry users are immediately in dangerous, poorly delineated avalanche terrain that commonly receives high winds and substantial snowfall.

Mt Bachelor (MTB)

The boundary at Mt Bachelor is also explicitly closed. They use signage but no rope lines to identify their boundary. There is one exception: an access gate that the public may use to get to Kwohl Butte (a cinder cone approximately 1.5 miles south of MTB). Users are required to enter and exit through this gate only. There are no specific gear or partner requirements.

WASHINGTON

Crystal Mountain (CM)

A user would be wise to study up on Crystal Mountain's policy before plunging into that blower pow. On CM's Web site they specifically reference the terrain adjacent to the ski area by its orientation to the ski area – e.g., east of Crystal, north of Crystal, etc. Depending on where you are at on CM, there may be, 1) no restrictions, 2) access gates (which may be opened and closed depending on whether you're entering true backcountry or the North/South Back regions), 3) permanent closures, or 4) hard rope lines which you may or may not be allowed to duck.

CM is a large ski area, the largest in Washington state. It shares boundaries with Forest Service land as well as Mt Rainier National Park. Its North and South Back areas contain extensive avalanche terrain, and avalanche-hazard reduction cannot always be performed. Depending on conditions, CM will close the gates that access the North and South Back. Access to the North and South Back is only permitted through gates. At boundaries that are not roped, CM uses signage to convey to the rider that they are leaving the ski area. CM recommends that users carry avalanche safety equipment and ride with a partner; however, they don't require it.

Stevens Pass (SP)

Full disclosure, I am a patroller at Stevens Pass. SP is a ski area that occupies terrain on all aspects and two different mountains. There are multiple ridgelines that run from the ski area for miles, accessing fantastic terrain. While our defined operational boundary is about 1100 acres, the adjacent terrain that gets ridden from direct lift access is much larger.

Our policy is that our boundary is open. We don't use rope lines to mark our boundary. We have signs that read "Ski Area Boundary," which are placed approximately every 20 feet along the boundary. There are four common points along our boundary where users typically exit the ski area. At these points there is additional signage *(see photo of signage, above, for exact wording)*.

We have no closed areas within our boundary. The exceptions are: 1) early season, when snow cover is such that rescue would be dangerous to the rescuer, and 2) when avalanche hazard is such that debris from an avalanche could reach our operational area. When one or both of these conditions are met we will use hard rope lines, "Stop Closed Area" signs, or both to convey the closure. Often we can restrict access to terrain where an avalanche could affect our operational area by posting CLOSED signs at the hiking route access points.

There is a large and active population of backcountry users who ski and ride at SP. Like CM, we suggest that users carry avalanche safety equipment and have a partner, but we don't require it. Unfortunately, in each of the past two seasons there have been avalanche-related fatalities in terrain that was accessed by our chairlifts.

Alpental

For the majority of the Seattle/South Puget Sound metropolis, Alpental is the shortest drive to lift-accessed backcountry – for some people an hour or less. Located along a major east-west freeway (I-90), the resorts of Summit at Snoqualmie see plenty of user days every season.

Alpental's backcountry policy is different from any other in Washington, in that their patrol issues a "Backcountry Registration Card." The card allows a guest who has been accompanied by Alpental Pro Patrol through the backcountry, to then ski/ride in that backcountry in the future. The only real stipulation is that the backcountry is only accessed through gates in what they refer to as "the Forever Rope," which is a rope line that marks the northern boundary of Alpental ski area. If the gates are closed, access is not allowed.

The rationale described in Alpental's Backcountry Policy and Release of Liability is that the gates are open when the patrol has determined that skiing/riding in the backcountry presents hazard only to the user or their immediate group. The policy then goes on to strongly recommend common safe travel practices and avalanche safety equipment. Gear and/or partners are not required.

There are four ski areas operated by Summit At Snoqualmie: Summit East, Summit West, Summit Central, and Alpental. For all intents and purposes, they are all located at Snoqualmie Pass, WA. As far as I understand it, the Backcountry Registration Card is only applicable in consideration of a specific area of "backcountry" adjacent to Alpental's regular operational area. This area is the Back Bowls, north of the northern boundary of the ski area.

Mt Baker Ski Area

Most people in the avalanche world are familiar with Baker if only because of its status as the current record holder for single season snowfall. 1998/99 wasn't a fluke. Baker enjoys an average annual snowfall of 641" (1628cm), the highest average at any developed ski area in the world. While comparatively small (1000 acres) as a major Pacific Northwest ski area, Baker is dense with avalanche terrain. It is near Mt Baker, the volcano, but not on its flanks. There are thousands of acres of backcountry avalanche terrain that are utilized in the immediate vicinity, including the infamous Shuksan Arm, which is a several-mile-long ridge that leads to Mt Shuksan, southeast of the ski area.

The boundary policy at Baker is one of the more complex, requiring diligent review by the riders there.

Continued on page 30 ➡

How to Avoid Liability in the Backcountry

Story & Photos by Rich Mrazik, Esq.

I know what you're thinking: Really? We need to be talking about this? If you're like me, you go to the mountains to escape worries about money, lawsuits, and liability. So why are we sullying the sanctity of the backcountry with a discussion of worldly concerns?

Because the backcountry is changing. The days of the rugged individual testing his or her mettle against the challenges of the mountains are giving way to the era of rugged individuals – *plural* – seeking the same experience in the same place at the same time. Blame it on the advent of gear that actually works (finally), slackcountry access as a gateway drug to backcountry addiction, or just the spreading gospel of untracked snow – it doesn't matter. There are more people out there and, as stated by the inimitable Bruce Tremper, people are a damned mess. We need rules; even in the backcountry.

The Golden Rule of Reasonable Care

There is really only one rule to remember: we all have a duty to use reasonable care to avoid injuring others. Not "hide under the bed and never go skiing again for fear of getting sued" kind of care, and not "avoid other human beings at all costs" kind of care – ***reasonable*** care.

The amount of care that is reasonable depends upon the situation. Ordinary circumstances do not require extraordinary caution. But some situations require more care because a reasonably careful person would understand that more danger is involved. You've probably heard stuff like this before; they are the same general concepts we use to avoid getting caught in an avalanche.

Noodling around in a low-angle meadow that is not connected to high-angle slopes? As long as you avoid T-boning another skier, you can go crazy! This is an ordinary circumstance requiring the bare minimum of care to avoid liability. (No matter what the old timers say, you cannot get sued for crossing someone's tracks.)

But what if you are feeling the stoke and considering riding that steep 3000' chute on a day of considerable danger? You need to STOP and THINK before dropping in. This is a circumstance requiring more care because more danger is involved – danger to you, and danger to others who may be recreating in the terrain below you, or driving on the road below you. To avoid liability, consider the likelihood and potential consequences of a slide, and then make a reasonable choice, which may be to come back another day. The law allows you to be as rad as you want to be – as long as you do not cause injury to people minding their own business.

Comparative Fault

Which brings us to the important concept that reasonable care is a two-way street. Just as we have a duty to use reasonable care to avoid causing injury to others, the law creates a strong incentive to avoid blundering into situations in which injury to ourselves is likely. The legal concept of comparative fault provides that if a plaintiff (the person bringing the lawsuit) is 50% or more at fault for the accident in which he is injured, the plaintiff recovers nothing. In other words, if the jury finds the plaintiff is at least 50% at fault, the defendant is not liable for the plaintiff's injuries. Everybody takes their proverbial ball and goes home.

Put bluntly, the concept of comparative fault is perhaps best understood as the "moron on the skin track" rule. If you choose to climb the gut of that steep chute on a day of considerable danger, and you are injured in a slide initiated by another skier, you are partially at fault because you failed to exercise reasonable care in choosing to climb the slide path. If you bring a lawsuit against the skier who triggered the slide, and the jury finds your fault for the circumstances that led to your injuries is equal to (or greater than) the skier who triggered the slide, you lose – you recover nothing.

And so, just as with the skier at the top of the chute, the law encourages the rider about to climb the slide path to STOP and THINK. What is the likelihood of an avalanche on this terrain? What are the consequences if a slide comes down this chute? If the answers to those questions suggest you will be injured in the event of a slide, the law encourages you to make a reasonable decision and climb another route.

Three Strategies to Avoid Liability

Against this legal background, and recognizing the devil is always in the details – snow offers thousands of shades of grey, but very little black and white – here are three strategies for avoiding legal liability in the backcountry:

The era of the rugged individual is giving way to the era of multiple rugged individuals sharing the same terrain at the same time.

1) Apply the Golden Rule.

Treat other backcountry enthusiasts the way you want them to treat you. If you were that guy trying to work his way between safe zones on the way up the slope, would you want someone to ski cut it above you? Probably not – so consider waiting for him to top out before putting your ski cut in. Conversely, if you were that rider on the ridge who busted his butt setting the skin track before dawn, would you want to look down and see someone having lunch in the middle of your hard-earned run? Probably not – so move to a safe zone, and let the guy on the ridge have his moment of glory.

2) Don't be a jerk.

If your version of applying the Golden Rule is "screw everyone, it's anarchy out here," you're being a jerk. And nothing attracts lawsuits like jerks.

3) Channel your inner Annie-dog.

Please allow me a brief digression. I have a dog, Annie, who is a 52-pound pit bull/lab mix – a fantastic combination of raw speed, brown fur, and love – whose sole mission in life is to chase an orange rubber ball as fast and as often as possible. (Replace the orange ball with untracked powder, and Annie starts to sound familiar.) Annie-dog has an unshakeable faith in the future. If she can't chase the ball today because it snowed too much to find the darn thing, "No problem!!" says Annie-dog, "the sun will come up tomorrow, and I'll chase it then."

If we all channel our inner Annie-dog – trusting it will snow again, we will get another chance to ski that chute in prime conditions, and realizing we do not need to sacrifice the safety of others or ourselves to chase our own orange rubber ball, whatever it might be – we will avoid liability in the backcountry. Better still, we will enjoy long, healthy, and happy mountain winters.

Rich Mrazik is a litigator with the Salt Lake City office of Parsons Behle & Latimer. Rich skis every chance he gets (regardless of snow quality), and he is proud to serve as the president of the board of the nonprofit arm of the Utah Avalanche Center. Rich is happy to accept questions and comments at rmrazik@parsonsbehle.com.

snow science

A powerful Pacific storm shook the Wasatch over the last days of February and early March of 2012. Ten natural and human-triggered slides – many remote – were reported to the Utah Avalanche Center on Friday, March 2, as the storm was winding down. It was the end of the avalanche cycle. Or was it?

The next day offered warming temperatures under overcast skies – some would use the term "greenhousing" – resulting in more human-triggered slides, no naturals. The following day dawned clear with temperatures spiking into the 40s; solar radiation skyrocketed above 250 W/m^2. And the house fell apart. Creep rates went through the roof, clearly exceeding the ductile to brittle threshold, with stresses concentrated along weak interfaces formed mid-February. By the end of the day, more than 35 size 2 and 3 naturals were reported to the Utah Avalanche Center.

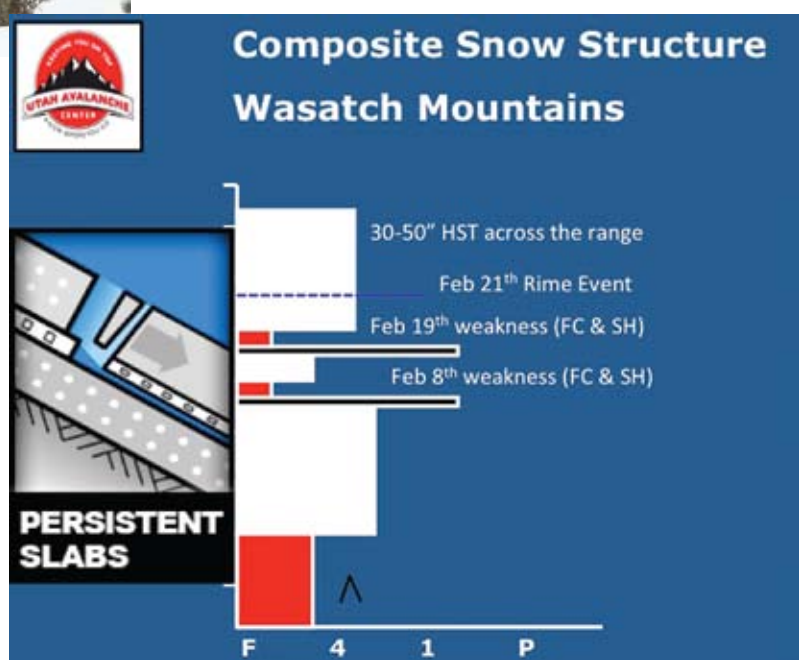
Gobblers SE broke and stepped down in the March 4 cycle.
Photo by Kevin McCurdy

Playing with Fire

Case Study of the March 4, 2012, Temperature/Solar Radiation-Induced, Dry-Slab Natural Avalanche Cycle and its Practical Implications for Forecasting

Story by Drew Hardesty

There are very few well-documented cases of dry-snow avalanches being triggered by warming. This study was originally presented at the Utah Snow and Avalanche Workshop in November 2012.



Imagine that your 10-year-old son is having a birthday, and the two of you are making a plate of brownies for the party. After it pops out of the oven, he doesn't think it's sweet enough. "Let's pour a bunch of sugar on the top," he exclaims, in clear disregard of his potentially skyrocketing blood sugar. But it's his birthday after all, so you pour it on – but it's still not sugary enough for him. "I have an idea! Let's pour a bunch of honey into a pan, throw it in the freezer for an hour, then slap the honey block on top of the sugar brownies!" How can you resist? An hour goes by, and all his 10-year-old bros can barely contain their excitement. You pull out the frozen block and set it upon the white granulated sugar capping the square of brownies. The whole thing is hard as a rock, so what to do? You grab the whole pan, take it to the window to catch the sun, and tilt the thing up at say, 38 degrees. Soon, the honey slowly begins to warm and then starts to flow...

On Sunday, March 4, 2012 – two days after a classic 30-50" Wasatch storm – the sun came out, the honey started to flow, and the house fell apart. More than 35 size 2 and 3, cold, dry-slab natural avalanches went reported to us at the Utah Avalanche Center. How many more went unseen or unreported? It was one of the more fascinating avalanche cycles I had ever seen.

What happened? This cycle had little to do with the monsters in the basement – some of the weakest basal depth hoar noted in years. The story began in February when two clear spells each produced a radiation-recrystallized facet-crust combination with subsequent snowfalls blanketing and preserving the weaknesses. Note the composite profile. A powerful Pacific storm then shook the Wasatch over the last days of February and early March with storm totals of 30-50" noted across the range. Storm totals from February 27 to March 2 recorded at the Alta Guard Station (8800' in Little Cottonwood Canyon) totaled 39.5"/2.44" H2O. The following report outlines what occurred over the next three days, from Friday, March 2 through Sunday, March 4.

FRIDAY, MARCH 2

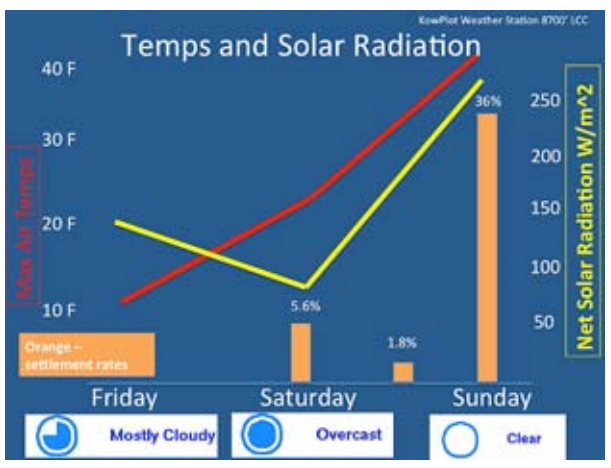
Ten size 2 or 3 naturals were reported to us. Skinning along a ridgeline, my own touring party remotely triggered a size 2 avalanche along the February 8 RR facet/crust interface in Silver Fork drainage. Nine other similar human-triggered slides were reported that day.

SATURDAY, MARCH 3

Zero naturals. Ten size 2 or 3 human-triggered avalanches were reported to the UAC.

SUNDAY, MARCH 4

Numerous human-triggered slides, but here's the kicker: 35 size 2 and 3 naturals were reported to the Utah Avalanche Center. Yes, you read that correctly: 35.



The weather graph above speaks for itself, but to point out a couple of the main considerations, note how the snow temperatures initially spiked on Saturday when we had warming, but overcast, skies. Temperatures jumped from a high of 23 degrees Saturday to 42 degrees on Sunday. Solar radiation input jumped from 428 W/m2 on Saturday (at 1430 hrs) to 913 W/m2 on Sunday (at 1300 hrs). Net solar

A nicely framed shot of Little Water East from Paul Daugherty, with its own natural avalanche from the avalanche cycle under discussion. *Photo by Paul Daugherty*

(input minus reflected solar) for the two days was 71 W/m2 on Saturday and 270 W/m2 on Sunday. Note how the vertical deformation – or settlement rates – skyrocketed from Saturday's 5.6% to Sunday's 36%. The rate was five times what it was on the previous, overcast-but-warm day…36 hours after the last snowflake hit the ground!

What was the pattern? All 35 of these reported avalanches failed on a facet/crust interface buried 2-4' deep on aspects primarily ranging from east-northeast southeast to south. These were all cold dry slabs where the warming affected the mechanics of the slab but did not penetrate down to the weak layer.

March 4 Checklist: *The Perfect Storm*

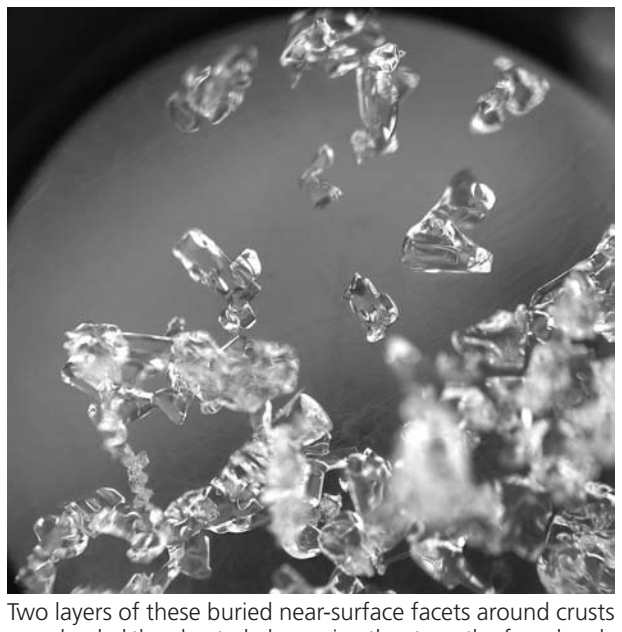
- ⊗ Persistent weak layer (or hardness, density, grain size interface)?
- ⊗ Good bed surface?
- ⊗ Slab? Or new storm snow becoming a slab?
- ⊗ Cold low-density new snow? More susceptible for deformation (vertical and horizontal).
- ⊗ First high solar input.
- ⊗ First high temperatures.
- ⊗ Snow warming may not be as important as solar radiation/temperatures.

A good number of researchers have looked at temperature effects on snow stability and they boil down to effects on slab stiffness/tensile strength and both the vertical (settlement) and slope parallel (creep) deformation rates. Exner/Jamieson *(2009)*, measured slope parallel speeds of .9-1.5mm/hr (roughly before their toothpicks melted out at 9:30am). Conway and others have measured rates of 10^-6m/s. Reiweger and Schweizer *(2010)*, found brittle behavior at strain rates faster than 10^-3m/s, which agrees with previous measurements on the ductile to brittle transition. Habermann *(2007)*, demonstrated that stress concentration at interfaces typically result in higher shear rates. Reiweger and Schweizer *(2010)*, found during lab experiments that different kinds of weak layers show that 90% or more of the deformation is concentrated within the weak layer, leading to strain rates 100-1000 times the global strain rates.

I suspect that our March 4 event had both things going on – with slab stiffness perhaps primarily complicit in the human-triggered slides, while creep-rate differential (as implied by the measured settlement rates at the Alta Guard Station) sparked the natural cycle.

In Provo Canyon on the Cascade ridgeline, Bill Nalli found this impressive dry slab example from the March 4 cycle. *Photo by Bill Nalli*

My take-home points are outlined in the checklist at left. In a nutshell: temperature and solar radiation are critical in and of themselves, but change in same maybe more so. The structured snowpack was also critical. Had the same weather parameters affected a homogenous un-layered snowpack and storm, I posit that the natural activity may have been minimal. Another key component was that the upper portion of snow affected was low-density powder snow that is more susceptible to deformation than higher density snow (or slabs). Last, but not least, perhaps snow temperature spikes may not be as crucial as the other factors.



Two layers of these buried near-surface facets around crusts were loaded then heated, decreasing the strength of an already provisionally unstable snowpack.

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Drew's been forecasting for the Utah Avalanche Center since 1999 and spends his summers as a Jenny Lake climbing ranger in Grand Teton National Park, a place he calls the "most romantic mountain range in the world." He recently went to Washington, DC, with a few other rangers and Exum guides to accept a Medal of Valor for the 2010 rescue of 17 lightning victims near the summit of the Grand Teton. As a forecaster, Drew says he draws upon his Kentucky upbringing to spin a few yarns on the avalanche report. He cites his previous employer, the cowboy philospher Al Brown, the French aviator Antoine de St Exupery, the dry-fly fisherman Norman Maclean, the Spanish Fathers Dominguez and Escalante, the whale hunter Herman Melville, Japanese poet Matsuo Basho, and, of course, Tom Kimbrough, as storytelling inspiration.

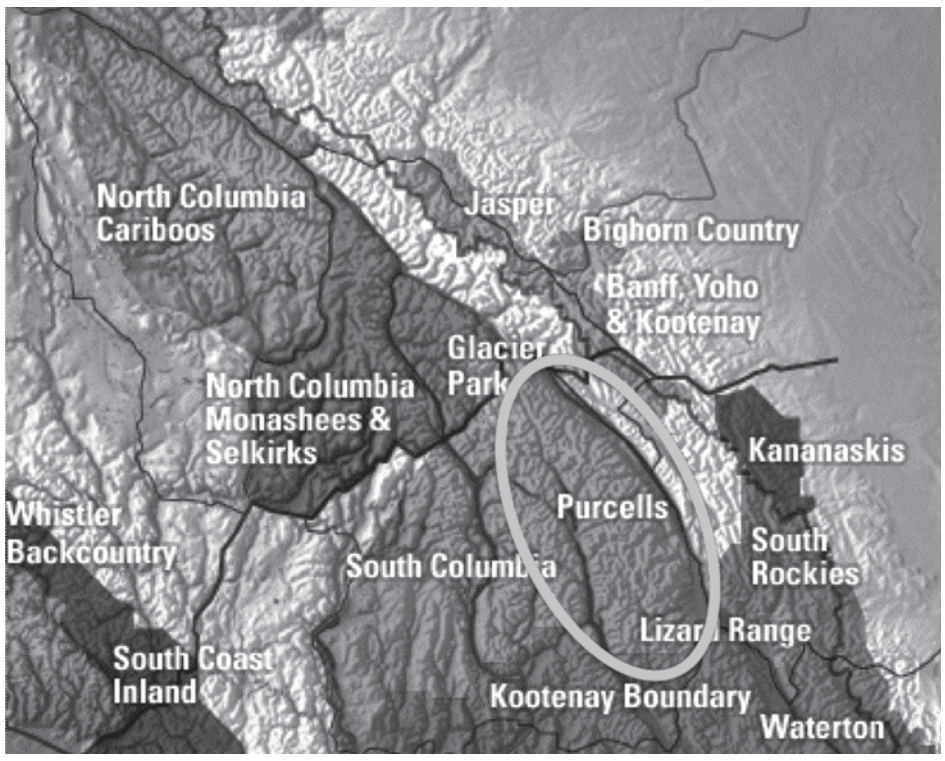
Temperature Effects
WARMING

Here Comes the Sun

Case study of an avalanche cycle in the Purcells, BC, February 2-3, 2012

Story by Thomas Exner

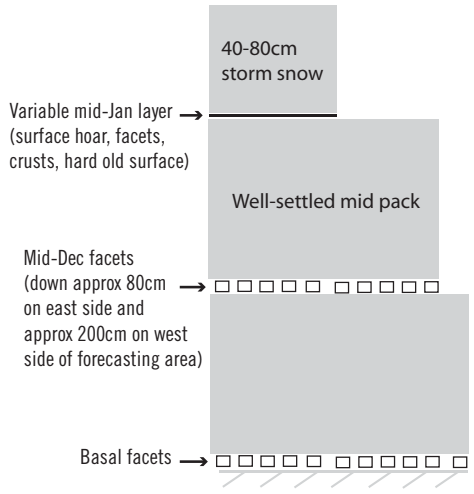
It's the first sunny day after a stormy period in early February. The forecast promises sunny, stable weather and mild temperatures for the following days. This time of year, many don't think about solar radiation as an avalanche trigger. In this case, however, how are the mild temperatures affecting the snowpack? Is the snowpack susceptible to stability changes due to the warming? To shed more light on these questions let's take a close look at the period from February 1-5, 2012, in the Purcell Mountains in BC. Note that we are discussing mid-winter, dry slab conditions, only the snow surface started to become moist on solar aspects. Typical spring conditions where most of the snowpack turns isothermal and becomes moist is quite a different story.



Forecasting areas in western Canada. This article refers to the Purcells area.

SNOWPACK

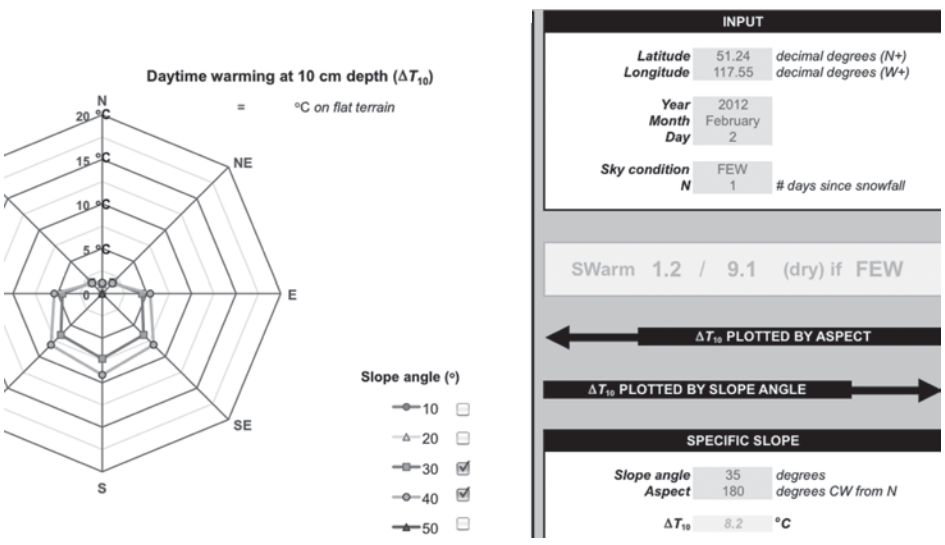
Before looking at the avalanche activity and the role solar radiation and warming air masses played, let's have a closer look at the snowpack structure prior to the warming period *(at right)*. This snowpack structure certainly contains some red flags hinting at a potentially unstable snowpack. Until February 1, however, the only avalanches observed were explosive-controlled small avalanches in shallow areas – releasing in the basal facets though. No other new avalanches were observed on February 1. Snowpack stability tests (mostly compression tests) yielded moderate to hard results with variable fracture qualities (few sudden fractures, mostly Q2 and Q3).



Average snowpack structure on February 1 before warming period.

WEATHER FORECAST

The Canadian Avalanche Centre (CAC) issued this weather forecast for the days after February 1: "The region may have seen the last drips and drabs of precipitation for a while. A strong ridge building from the western part of the province [BC] will bring drier conditions for the forecast period. On Thursday [February 2]… freezing levels may rise to 1200m and alpine temperatures steady near -5. Friday [February 3] and Saturday the ridge of high pressure holds true with freezing levels potentially reaching 1800m."



Snowpack warming model: Swarm. SWarm is available for download on www.ucalgary.ca/asarc/. For more info on SWarm, check out the training video on vimeo.com/27930973

THE AVALANCHE CYCLE

This "primed" snowpack with a number of embedded weak layers in combination with the warming trend resulted in an avalanche cycle as reported by the CAC on February 4: "Since the recent warming, numerous large and destructive avalanches (to size 3.5) were reported in the region. Most of the avalanches were specific to south-facing alpine features. Some of these avalanches were initiated by cornice fall. Others were loose, wet avalanches that, in some cases, stepped down to basal weaknesses."

More details about this cycle and actual weather observations are given in Table 1. Freezing levels reflect an average for the Purcell area taken from observations. The daytime warming ΔT (difference between coldest snow temperatures in the morning and warmest temperature in the afternoon due to solar warming only at 10cm snow depth) was calculated with the snowpack warming model SWarm *(see above)*.

No new avalanches were observed in the Purcell area on February 1; freezing levels were quite low and an overcast sky kept the snowpack cool. The warming trend on February 2 (rising air temperatures and strong solar warming) contributed to a widespread avalanche cycle in the forecast region with large avalanches up to size 3.5. The cycle intensified on February 3 with still-strong solar radiation and rising freezing levels. Surprisingly, on February 4 no new avalanches were observed despite the fact that warming conditions were similar to the day before. Likely, the snowpack kept settling and stabilizing with the ongoing warming trend. On sun-exposed aspects a melt-freeze crust formed overnight to give the snowpack more stability, especially in the morning. The fact that a lot of avalanches released on SE- to SW-facing aspects suggests that warming of the snowpack due to solar radiation played a major role in this avalanche cycle. As also known from other cases, the onset of the warming period (first sunny day after a storm) seems to have the strongest impact on deteriorating stability. Similar observations are reported by Drew Hardesty in this issue *(see page 22)*. It is no surprise that on February 5 no new avalanches released with freezing levels lowering close to valley bottoms despite another day of strong solar radiation.

TABLE 1: Overview of weather conditions and avalanche activity during the warming period February 1-5, 2012, in the Purcells, BC.

	February 1	February 2	February 3	February 4	February 5
FREEZING LEVEL	below 1000m	1000-1300m	above 2000m	1500-2000m	below 1000m
CLOUDINESS	Overcast	Few - Clear	Few - Clear	Clear	Clear
SOLAR WARMING ΔT [°C] for 35° steep N & S	1.7 / 1.7	1.1 / 8.2	1.2 / 9.0	0.8 / 11.0	0.9 /11.6
AVALANCHE ACTIVITY	No new NA & SA; Only 2 XE	Numerous NA to size 3.5; also deeper layers	Peak of cycle; up to size 3.5 & wide propagation	No new avi obs	No new avi obs

NA = natural avalanche, SA = skier accidental, XE = explosive triggered

THE CHALLENGE TO FORESEE THE WARMING EFFECT ON STABILITY

In hindsight it seems obvious that the combination of intense solar radiation and high freezing levels (solar heating likely was the primary effect) contributed to cause this avalanche cycle of a "primed" snowpack. Prior to the warming, however, to actually foresee this cycle has proven to be substantially challenging. Even experienced forecasters were surprised by the impact of the warming and extent of the cycle. Why? The following points are speculations why the warming effect may have been underestimated:

- First of all, freezing levels turned out to rise considerably higher than anticipated in the weather forecast.
- The stormy period before the high-pressure system only added more storm snow in bits and pieces. The cumulative loading effect may have been overlooked.
- Not seeing any natural activity and human-triggered avalanches prior to the warming-induced cycle may have led forecasters to underestimate the reactivity of the snowpack structure.
- The solar effect on the snowpack in early February can easily be overlooked. (SWarm is a great tool to train one's awareness of the impact of solar radiation.)

KEY TAKE-HOME POINTS

- Warming alone likely does not cause instability (of a dry slab). A susceptible slab/weak layer combination is necessary.
- The first exposure to solar radiation largely contributed to instability in this case study. The rising freezing levels contributed, but snowpack warming due to warm air masses is usually quite a slow process. Prolonged warming likely helps to stabilize the snowpack.
- The effect of solar warming on snowpack stability is difficult to forecast and can easily be overlooked.

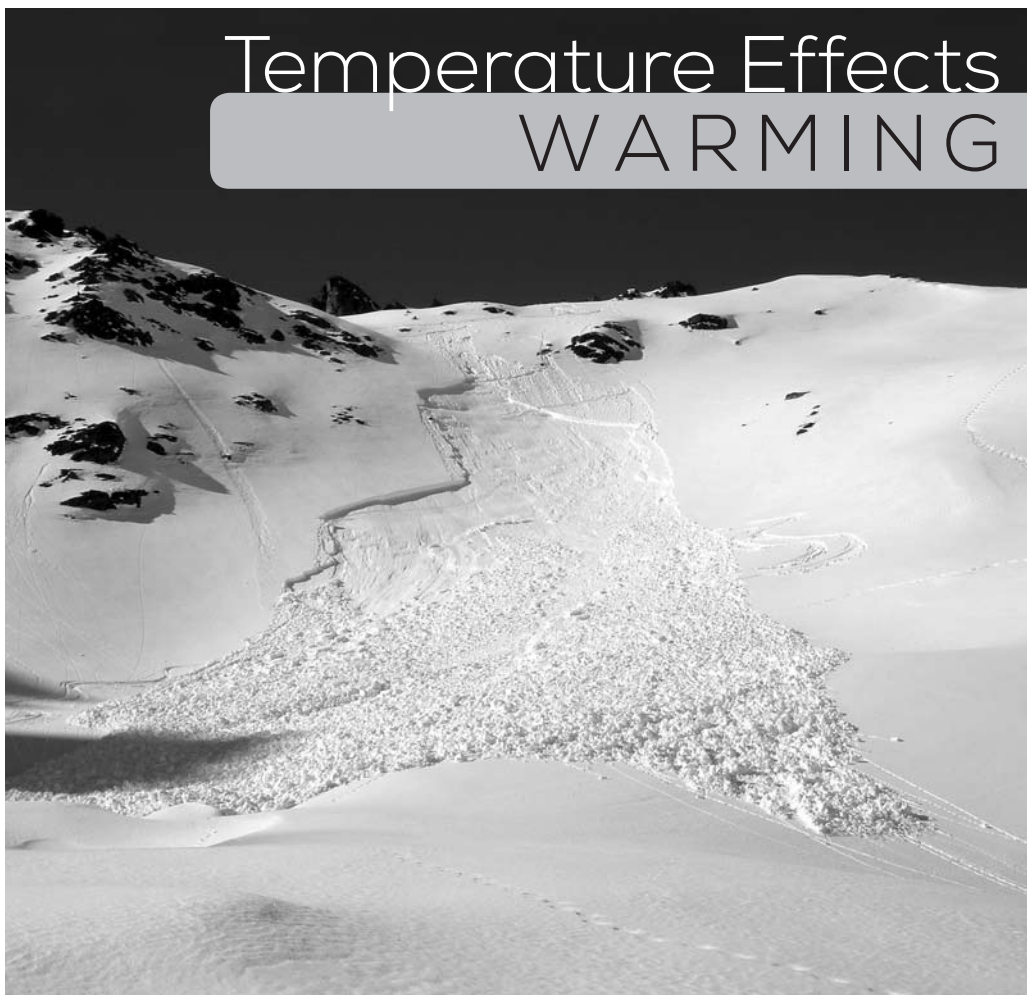
A training video of this case study is available on the ASARC Web page (www.ucalgary.ca/asarc/research/outreach). For more on how surface warming affects stability, see the article by Schweizer, Reuter and Jamieson on the next page.

Thomas Exner was born and raised in the Bavarian Alps. He has spent recent winters in the mountains of western Canada studying avalanches with the University of Calgary where he graduated with a PhD. As an internationally certified mountain guide (IFMGA) he continues to work in the European Alps and Canada.

How Surface Warming Affects Dry-Snow Instability

Story by Jürg Schweizer, Bruce Jamieson, and Benjamin Reuter

Warming is believed to be one of the most prominent causes of snow instability – although experimental evidence is rare. We know that due to the low thermal conductivity of snow, warming at the snow surface rarely affects the weak layer temperature. In the case of dry-snow slab avalanches, instability is not due to weakening of the weak layer, but is believed to be due to increased deformation within the near-surface layers of the slab. Solar radiation can penetrate the surface and effectively reduce the stiffness of the upper layers. Changing slab properties directly affect snow instability in many ways. Recent field measurements provide insight into the processes believed to promote dry-snow instability. But still, field evidence is rare, which is also because the effects of surface warming are subtle and likely only promote instability during certain slab/weak layer conditions.



Dry-snow slab avalanche triggered on February 24, 2008, 2500m a.s.l., ENE; Avalanche danger level: "Low" (since eight days); Air temperature = +5°C, Temperature change = +6°C, warm southerly wind ("Föhn"): Surface warming – or freak avalanche? *Photo courtesy Jürg Schweizer*

INTRODUCTION

Apart from precipitation and loading by wind, a rapid increase in air temperature and/or in solar radiation is commonly considered a meteorological factor contributing to snow instability under dry-snow conditions. Despite the fact that the rule of thumb, "A rapid significant increase in air temperature leads to instability," is widely stated in avalanche education *(e.g., Munter, 2003)*, data to support this rule are rather sparse.

After an avalanche release often no other obvious external factor can be found. Harvey and Signorell *(2002)* reported that in 20% of the recreational accidents in the Swiss Alps an increase in air temperature (from the day before the accident) was the only indicator of instability. On the other hand, in many of the statistical avalanche forecasting models, temperature – but also the temperature change – ranks consistently low among the meteorological forecasting parameters *(e.g., Davis, et al., 1999; Schirmer et al., 2009; Schweizer and Föhn, 1996)*. In fact, in some of the leading textbooks *(McClung and Schaerer, 2006; Tremper, 2008)* suggest that the effect of warming on dry-snow stability is probably relatively small or only prominent under very special circumstances. Still, temperature (and radiation) is listed as one of the five main contributing factors (terrain, precipitation, wind, temperature/radiation, and snow stratigraphy) in Schweizer, et al. *(2003)*. They suggested that instability would be due to changing slab rather than weak layer properties, and that radiation would be more efficient than increasing air temperature in causing instability.

In the following we will briefly review some key elements on surface warming and its effects on snow instability – this is not a comprehensive review of the temperature effect.

DEFINITIONS, PROPERTIES, AND PROCESSES

To set the stage we first define the relevant terms and conditions. First of all, we focus on dry-snow conditions and dry-snow slab avalanches. With surface warming we mean that in the surface layers of the snowpack (i.e., in the upper layers of the slab) snow temperature increases. The temperature increase is due to a net energy flux directed into the snowpack which indicates an energy gain *(King, et al., 2008)*. The net surface flux is the sum of surface fluxes (shortwave radiation, longwave radiation, and turbulent fluxes of sensible and latent heat) neglecting latent or sensible heat added by precipitation or blowing snow and ground heat fluxes. Describing conditions by which the snowpack gains energy is complex, but occur mostly with intense solar radiation and/or an air temperature significantly warmer than the snow surface temperature accompanied by wind (wind is a necessary condition). Still, the snowpack only gains energy if these fluxes, the net solar radiation and the sensible heat flux, are not compensated by the energy loss due to the net longwave radiation flux.

Since the thermal conductivity of snow is low, the energy added to the snowpack by sensible heat travels slowly from the snow surface to the layer beneath *(e.g., Fierz, et al., 2008)*. In contrast, the energy input by shortwave solar radiation more efficiently warms the surface layers as the radiation penetrates into the near-surface layers (so that the energy is released within the snowpack). However, shortwave radiation penetration strongly decreases with depth below the snow surface. Compared to solar radiation, an increase in air temperature by 10°C from one day to the next will affect the snowpack to a depth of, say, 20cm much later and in attenuated form. Diurnal changes in air temperature over snow-covered surfaces are mostly not significant for surface warming, but diurnal changes in snow temperature in near-surface layers are predominantly due to absorbed solar radiation. Figure 1 *(on page 30)* shows an example of measured snow temperatures. In the course of the day, snow temperatures rose most remarkably in upper layers due to solar radiation on a southwest-facing slope. During the last time step, the snow already started to cool down due to the decrease in incoming shortwave radiation. Typically, significant surface warming takes place in the uppermost 20-30cm *(Fierz, 2011)*. A temperature increase of 10°C 10cm below the snow surface is common on south-facing slopes on sunny days *(Bakermans and Jamieson, 2008)*.

By the way, cooling – the opposite effect – is mainly due to heat loss by outgoing longwave radiation. The low thermal conductivity will cause cooling to take more time than warming by penetrating shortwave radiation.

Having identified the sources, conditions, and magnitude for surface warming we move on to the effect of changing snow temperatures on the mechanical properties of snow, and ultimately to stability. With snow being within a few degrees of its melting point, there is no doubt that changes in snow temperature strongly affect the mechanical properties, especially as the melting point is approached. Based on strength measurements in the cold laboratory, McClung and Schweizer *(1999)* concluded that the stiffness (effective modulus) of snow would be the property most sensitive to temperature, with strength being much less influenced. With increasing temperature the stiffness decreases – in other words, deformation in the near-surface layers increases, both in slope parallel as well as vertical direction (settlement). In fact, Exner and Jamieson *(2009)* have observed the increased deformation. If the temperature change in the near-surface layers is primarily due to the instantaneous release of energy from absorption of shortwave radiation, the change in mechanical properties is rapid as well. The change of the modulus in the near-surface layers has recently been determined from Snow Micro Penetrometer (SMP) measurements *(see Figure 2 on page 30)*. Over a few hours of solar radiation on a suitably inclined slope, cumulative energy inputs at the snow surface exceeded 300 kJ/m2 and caused the effective modulus of the surface layers to decrease by almost a factor of two on average *(Reuter and Schweizer, 2012)*.

Warming of near-surface layers affects mechanical slab properties resulting in increased deformation.

POTENTIAL MECHANISMS FOR PROMOTING INSTABILITY

For a dry-snow slab avalanche to release, a weak layer below a cohesive slab is required. An initial failure in the weak layer has to be initiated and needs to develop into a self-propagating crack below the slab. Surface warming is an external perturbation (trigger) that acts

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Temperature Effects
COOLING

Cooling & Avalanches

Cool-Down Avalanches during periods of rapid refreezing can catch forecasters by surprise

Story by Penny Goddard

Treble Cone ski area in New Zealand: Saddle Basin was closed during the day due to creep and glide concerns. At 5pm the surface was starting to refreeze, so the forecaster gave the OK for groomer operators to go into the basin to work. The avalanche occurred sometime during the night, failing on depth hoar at ground. It damaged the lift bull wheel.

Avalanches that occur during periods of cooling are important because they can surprise people.

The subject first piqued my interest several years ago. I was sitting outside a ski lodge at the end of a hot spring day, watching the sun leave a steep slope on the opposite side of the valley. A few minutes later, a large slab released from the slope. It seemed incongruous, as no obvious trigger was present: no recent loading by wind, snow or rain; no person; and no bomb. The only change I could perceive was a rapid drop in temperature as the slope moved from full sunshine to shade and into its associated early evening chill. A few days later, I saw the exact same thing on the exact same slope.

In 2005, I took on the role of avalanche forecaster at Broken River Ski Club. Lingering in the shadows of my mind was an avalanche that had occurred there 13 years before. The week preceding the avalanche had been stormy, with 142mm of precipitation. Fluctuating freezing levels eventually led to a rain-soaked snowpack. On the day of the avalanche, the weather cleared, temperatures dropped, and the snow surface became slick and icy. Staff decided to open the area based on conventional wisdom: cooling and surface refreezing promote stability. At lunchtime, a size D4 avalanche failed near the ground on depth hoar, pulling out the entire Broken River basin with a crown up to 2.2m deep, which propagated 800m wide into low-angle terrain, leaving a deposit 20-30m deep. A snow groomer and skiers were in parts of the basin and may have been the trigger, but they were far from the fracture line. Amazingly, only one person (the ski area manager) was killed, as almost all the other skiers were inside having lunch. A photo of the avalanche hung on the wall in the forecasting office, leaving me chilled and uncertain. Doesn't an icy, frozen surface mean the snowpack's locked up? Why did the avalanche fail then and not during the warm storm? Why did it propagate so widely?

So began my investigation. I started by turning to the books to read up on this phenomenon and learn about the mechanisms behind such events. Beyond some passing references to rapid temperature changes, the standard volley of avalanche reference books left me empty-handed. I tried scientific journals, asked academics, and searched online. Very little came to light. So I began to ask my colleagues. A few people had experienced something like that. Many hadn't.

A more formal questionnaire followed. In the end, 40 avalanche professionals from around the world responded. The questionnaire focussed specifically on "refreeze" type events (where the snow surface goes from 0°C to below 0°C). I called this a "Cool-Down Avalanche" or CDA for short. The responses alerted me to the prevalence of surprising, large avalanches during periods of rapid cooling, not just when the snow surface goes from melt to freeze, but also at overall lower temperatures (e.g., a drop from -5°C to -15°C).

This article firstly summarizes the results of the questionnaire, then highlights a round of cooling-related avalanches in Western Canada during the 2010/11 winter season.

PART 1: CDA QUESTIONNAIRE RESULTS

In order of descending quantity, observations came from New Zealand, North America, Europe, Asia, and Antarctica.

- 15 of the 40 respondents had never experienced a CDA. (Many more people elected not to answer the questionnaire at all, due to having never experienced a CDA.)
- About 360 CDA were observed (this number is approximate, as the bulk of observations were poorly recorded, based instead on observers' memories).
- 98% of observed CDA were described as slab avalanches, 2% as loose.
- The bulk of the observed avalanches were size D2-D3. 14 were size D4, and three were size D5.
- 61% were described as "glide" releases.
- 20 CDA events occurred within 15-60 minutes of the sun leaving the slope. Another seven occurred less than 15 minutes after the sun left the slope.
- 21% of respondents had experienced a close call involving a CDA. These included very large avalanches hitting an open highway, burying a ski lift in an area that was open to staff and fully burying people in guided groups.
- 38% of respondents factor CDA into their decision-making while managing the exposure of people and infrastructure to avalanches. 44% said they do not.
- Seven people who had never had a close call involving a CDA factor the possibility of CDAs into their decision-making. Interestingly, three people do not factor CDAs into their decision-making, in spite of having had a close call involving a CDA (including involvement in fatal incidents).

The following comments made by respondents address some of the reasons why CDAs are rarely factored into operational forecasting:

- "[This is] much too speculative a theory to apply in an operational forecast."
- "I see 'cool-down' as the more stable end of the curve."
- "I don't factor CDAs into management due to a lack of understanding and observations."
- "I don't factor CDAs in, as it seems a very rare event."
- "I don't factor CDAs in, as there's no knowledge base, therefore they are hard to estimate."
- "The funny thing is, I probably still guide and operate considering cooling down as a good tick for stability."

CDA CONCLUSIONS

- CDAs (surface refreezing avalanches) were observed around the world.
- Accidents and near-misses have occurred when operators have re-opened previously closed terrain assuming that cooling means dramatically improved stability.
- Some operators actively manage the CDA hazard through closures or explosives control, timed to coincide with rapid cooling or surface refreezing.
- They were rarely observed overall; many experienced practitioners have never experienced a CDA.
- There's a feeling that they are too difficult to predict, so there's a tendency to ignore them when making decisions.

Ski patroller Ed Nepia at the crown wall of the Treble Cone avalanche. Hard refrozen snow jutted out like a diving board above soft, moist snow below. Similarly shaped crown walls were reported from various CDA events.

Treble Cone photos by Dean Staples

PART 2: COOLING EVENTS IN WESTERN CANADA DURING WINTER 2010/11

Before I launch into Part 2, it's important to distinguish a key difference between Part 1 and Part 2. The questionnaire in Part 1 asked specifically about "refreeze" CDA events (snow surface going from 0°C to below 0°C). The events listed in Part 2 occurred during periods of rapid cooling within an overall colder temperature regime and did not involve a clear melt-freeze process at the surface.

The photos show a succession of large avalanches which occurred during periods of rapid cooling in western Canada. Operators described these events as very surprising, eye-opening, historic, and unusual.

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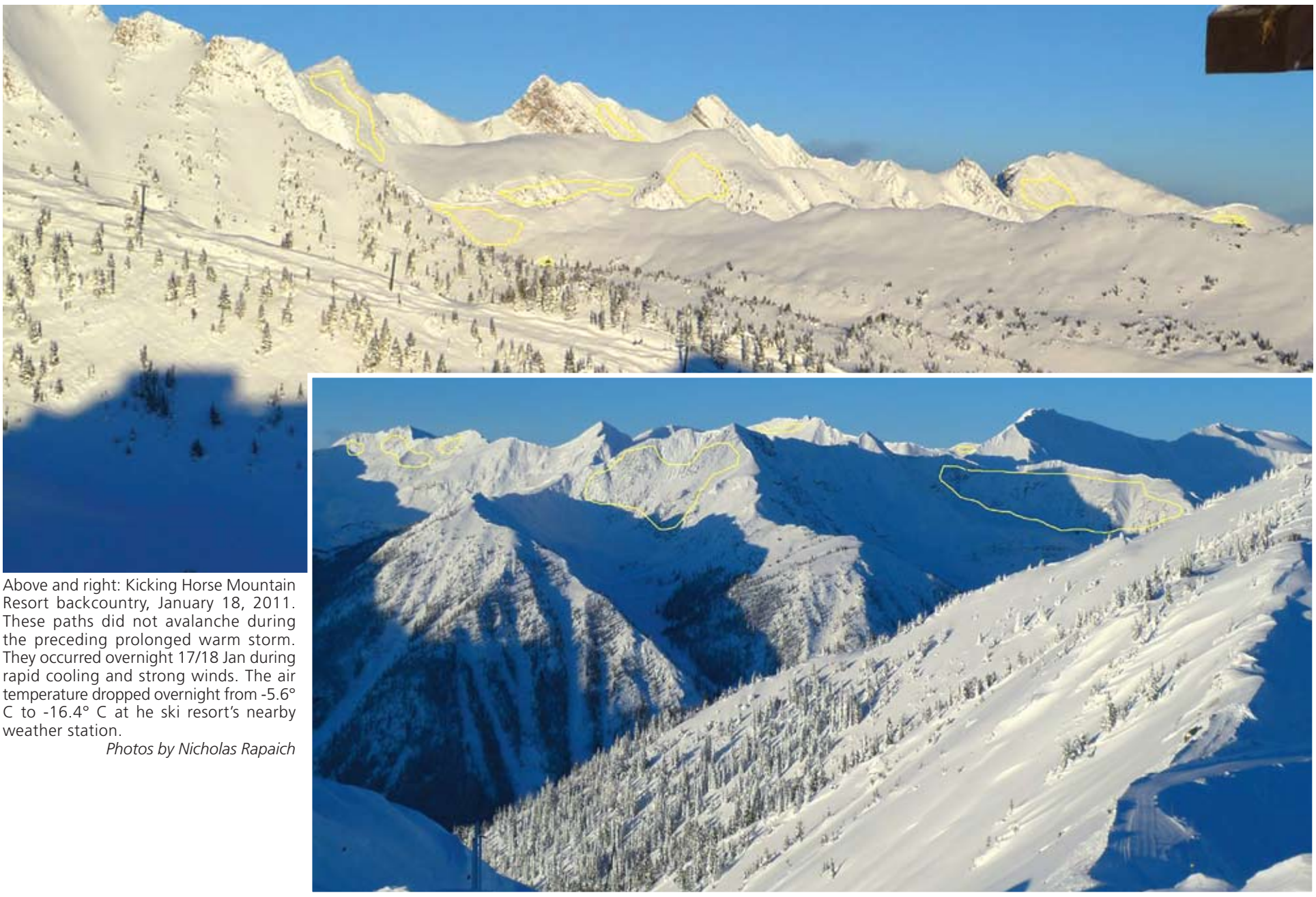
Monashee Powder Snowcats, Southern Cross Path, January 8-9, 2011. Overnight there was no appreciable new snow, no sign of wind, skies were clear most of the night, and temperatures dropped from -8.5°C to -15°C by morning. This was a size-D4, step-down slab, with very wide propagation. The trigger was a small cornice or small slope above. The lead forecaster said, "I'm busy rethinking my assumptions/intuition." (The guides were considering expanding their scope of terrain use that day). *Photo by Fiona Coupland*



Above and right: Kicking Horse Mountain Resort backcountry, January 18, 2011. These paths did not avalanche during the preceding prolonged warm storm. They occurred overnight 17/18 Jan during rapid cooling and strong winds. The air temperature dropped overnight from -5.6° C to -16.4° C at he ski resort's nearby weather station.

Photos by Nicholas Rapaich

Mistaya Lodge, western Rockies: Overnight January 17-18, 2011, after a storm that had deposited 1m+ snow. There was overnight air temperature cooling from -3°C to -13°C and wind (however, many of these slopes were not lee to the wind). More than 20 avalanches released, size D1 to D3.5 (many D2-2.5) with crowns 100-150cm; some up to 200cm deep. Several avalanches were observed in unusual locations. *Photo by David Birne*

Castor Peak, Glacier National Park, 8am, January 18, 2011. Under the same weather conditions affecting the Lanark Path (below left), this widely-propagating avalanche occurred. A second, historic avalanche occurred around the same time on nearby Crawford Peak, destroying mature timber in the runout. The surprising nature of these events led the Canadian Avalanche Centre to issue this warning message to operators on January 18: "Notable avalanche activity: We have received a couple of reports of large, unusual avalanches that occurred this morning as the temperatures were cooling…" *Photo by Kevin Boekholt*

Lanark path, Rogers Pass: 8am, January 18, 2011. The avalanche was size D4.5 and damaged 10 acres of forest. It failed on facets/crust at ground. The air temperature dropped from -3°C to -17°C overnight prior to the event. The avalanche cycle was considered to be over. This one failed near the time that sun first hit the slope. *Photo by MOT, Canada*

Golden backcountry: Dogtooth Range, overnight February 7-8, 2011. There had been no avalanche activity during warming on February 7. Overnight, the air temperature dropped from -10°C to -17°C, and these and other large slabs released. *Photo by Thomas Exner*

Temperature Effects
HIGH ALTITUDE

A powder cloud across the glacier from Latok 1 Pakistan dusts camp.

Temperature-Induced Dry-Snow Avalanches

Story & Photos by Doug Chabot

Statements of "warming-triggered" dry-snow avalanches have become common in the last few years. The public mentions it frequently, and it is increasingly referred to in avalanche advisories and classes. The evidence presented includes increased creep rates, wild swings in net solar radiation, and avalanche activity occurring naturally and with human triggers due to warming temperatures. These statements occur with certainty and regularity but with scant data. In order to witness temperature-induced avalanches a perfect lab would be one where large temperature swings occur consistently along with year-round snowfall. One of the best places on Earth to witness the effect of diurnal temperature changes on a snowpack are in the highest mountains of the world, where I've been lucky enough to spend my spring or summer over the last 20 years. While alpine climbing in the Karakorum, Himalaya, and Alaska ranges I've experienced the uncomfortable effects of rapid and dramatic temperature swings: t-shirt to down parka in minutes. These ranges are natural labs. If cooling or warming are big factors in triggering avalanches it would be witnessed here.

High mountains are an extreme radiation environment, with large amounts of incoming solar radiation during sunny days, and huge losses in longwave radiation at night. I've routinely seen evidence of this daily flip-flopping through the formation of diurnal recrystallization facets, formed faster at high altitudes than I've ever seen in Montana. Although cooling or warming air temperatures are parts of the energy balance, the energy balance for the snow is driven largely by the radiation balance. I don't carry scientific gear with me into the mountains. I do not have a robust data set, nor do I pretend to know exactly what happens to the snow with large air temperature changes. But I have never seen what I would interpret as a temperature-induced, dry-snow avalanche. That's to not say I can't or won't see it, but it's certainly not a primary or even secondary avalanche concern.

Since the 1990s I've spent more than two years living on glaciers: climbing, watching, and doing my best to not get caught in avalanches. In this time I've seen a hundred or more dry-snow avalanches and even triggered a few. All of them were due to at least one of these big three factors: it snowed, the wind blew, or there was poor snow structure, matching what I've seen for 15 years as an avalanche specialist on the Gallatin National Forest. These three things are a recurring problem the world over, and it's what I concentrate on.

Diurnal recrystallization at high altitudes creates facets quickly. These were formed in India at 19,000' within 24 hours and were buried the next day. Three climbers died in an avalanche on a nearby peak when the new snow slid.

Temperature changes are real, but the best available information we have indicates that their effect on triggering dry-snow avalanches only exists if the snowpack is already very close to instability. Every day the sun sets and the temperature plummets; the next day it rises and warms. Yet avalanches don't happen daily. It's an extremely rare event when multiple factors with weather and snowpack line up to be influenced by a temperature swing. Consequently, I've relegated warming to a low-level concern, something that may increase instability at a very minor level as a secondary contributor to the big three. Schweitzer and Jamieson said as much in their 2010 ISSW poster, *On Surface Warming and Snow Stability*.

An avalanche releases down an unnamed ridge near Latok 2.

Weird, unexplainable, head-scratching avalanche cycles will always happen and challenge our thinking. As avalanche professionals it's our duty to look into these cycles, but as professionals it's our duty to speak with clarity and not confuse the public. It's dangerous to pretend to know something we don't. Avalanches scare me because I can never understand them as well as I'd like. Pretending otherwise can kill me as a climber and skier. Pretending otherwise can kill others in my job as an avalanche specialist. Let's keep our eyes on the obvious red flags. People die in avalanches because of new snow, wind, and poor snow structure, not because they were out at 1pm on a sunny mid-winter day. Focusing on the nuances of temperature-induced avalanches can muddle our message as avalanche forecasters and is a dangerous distraction for those with a less complete understanding of avalanches.

Doug Chabot balances a career as director of the Gallatin National Forest Avalanche Center with a drive for mountaineering and exploration in the remote and high ranges of the world.

Temperature Effects
OVERVIEW

A Look Under the Hood

The effect of surface warming on snow stability

Story by Ron Simenhois

After the Utah Snow and Avalanche Workshop, Lynne asked if I'd be interested in writing a short article about the mechanics behind the processes that led to the March 4 Utah avalanche cycle. The reasons behind my positive answer may be a good decision-making case study and clearly didn't include what Alec van Herwijnen kindly reminded me about a week later: large parts of the mechanics leading to natural avalanche release are still unknown. In addition, there is very little snowpack data available from the March 4 avalanche cycle in the Wasatch. Hence, in this article I will try to give a general explanation of the effect of surface warming on crack propagation. I will also underline the areas where our knowledge falls short and will bring a few possible scenarios that may lead to natural avalanche release due to surface warming.

The idea that surface warming can contribute to snowpack instability is not new. With regard to skier-triggering, McClung and Schweizer *(1999)* concluded that the most important effect is the decrease of slab hardness (stiffness) with warming. More recent studies have shown that surface warming can increase the propensity for crack propagation. Simenhois and Birkeland *(2008)* presented two datasets where side-by-side ECT test results changed from ECTN to ECTP with surface warming, suggesting that the critical crack length decreased with surface warming. They also backed their results with case studies where slopes avalanched later in the afternoon when the snow surface was warm even though they had been tested in the morning when the snow surface was cold and didn't avalanche. It is important to note that in this work the warming was much more than simply warming up the snow a few degrees.

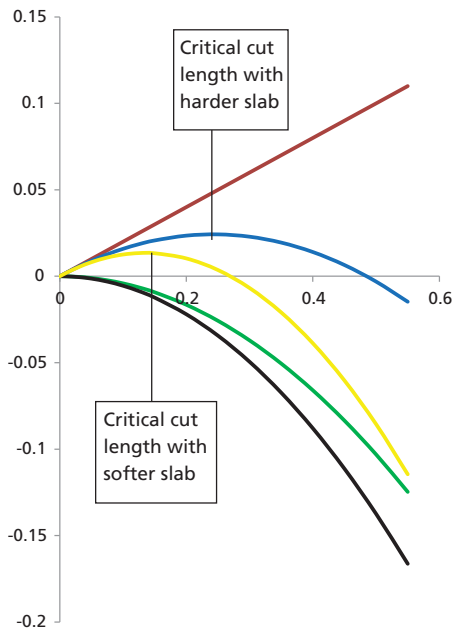


Figure 1: The fracture energy balance of the example cited in the text. Surface energy is in red, the mechanical energy when the slab elastic modulus is 1.2MPa is in blue, and the sum of the two energies is in green. The critical crack length is the value where the combined energy function reaches its saddle. In yellow and black are the total energy of the system and the mechanical energy, respectively, for the case the elastic modulus is reduced to 0.9MPa.

In all cases, the snow surface was melting. This is certainly the extreme case since changes in the snowpack accelerate rapidly as we approach the melting point. Thus, these preliminary and limited data really only apply to situations with snow-surface temperatures at the melting point and not to cold, dry slabs that are warmed up a few degrees.

Reuter and Schweizer *(2012)* measured changes in crack propagation in relation to the energy input at the snow surface (this is the overall energy changing the snowpack's temperature. Long-wave radiation and turbulent energy fluxes are also included). They measured and modeled changes in slab hardness (effective modulus), weak layer fracture energy and critical cut lengths of

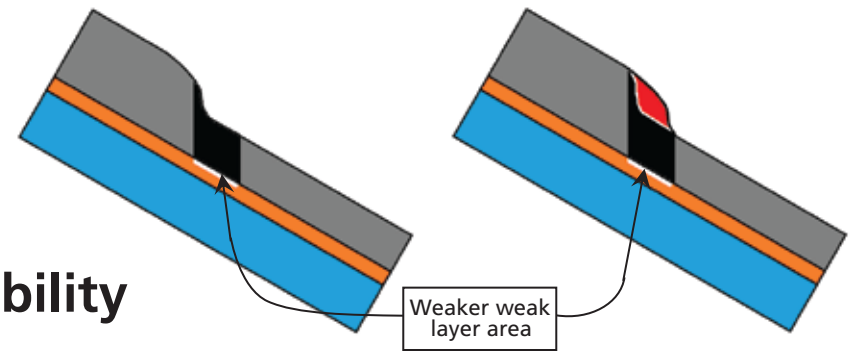


Figure 2: Graphic illustration of possible load increase on weaker weak layer areas due to surface creep. On the left is a possible scenario prior to surface creep – the load on the weak area is in black. The diagram at right shows a load increase after surface creep occurs – the red area indicates the additional load on the weak area.

Propagation Saw Tests on nine days with high incoming solar radiation. Their data showed that a cumulative energy input of above 400 KJm-2 coincided with decreases in slab hardness and shorter PST cut lengths. Furthermore, they did not observe any change in weak layer fracture energy. They therefore concluded that the increase in crack propagation propensity, as suggested by in the decrease of PST's critical cut lengths, was caused by an increase in energy release rate due to increased slab bending. Overall, changes in critical cut length were very subtle, strongly suggesting that both a preexisting weakness and significant energy input are required for surface warming to promote instability. Also, even in their carefully controlled data there is a great deal of scatter, pointing out the challenges of using these relationships in a forecasting context.

What is the energy release rate, how does surface warming affect it, and what does that mean for avalanche release?

Griffith's energy-balance approach shows that conditions are favorable for crack propagation when the mechanical energy release rate (rate per area, not time) of the slab exceeds the energy that must be expended for a crack to propagate over the same area. When a crack grows in the weak layer, a region of the slab above the crack subsides, and its strain energy is released. The total strain energy released is negative when the work it takes to bend the slab over the crack to the same depth it subsides and is given by:

$$\text{strain energy} \sim \frac{(\text{load})^2 \times (\text{crack length})^2}{\text{slab elastic modulus}}$$

The elastic modulus is a material property of hardness. More strain energy is released by increasing the crack length. But in creating a longer crack, bonds must be broken, and the fracturing energy is in effect absorbed by the weak layer. The energy that is needed to break the weak layer is related to the crack length. The total energy associated with the crack is the sum of the (positive) energy absorbed to create the new surfaces (surface energy), plus the strain energy that released by allowing the regions above the crack to subside. As the crack grows longer, the quadratic dependence of strain energy on crack length eventually dominates the surface energy, and beyond a critical crack length the system can lower its energy by letting the crack grow still longer. Beyond that point, crack growth is spontaneous and catastrophic. The value of the critical crack length can be found by setting the derivative of the total energy to zero *(see figure 1)*. This critical crack length is given by:

$$\text{critical crack length} \sim \frac{\text{weak layer fracture energy} \times \text{slab's elastic modulus}}{(\text{load})^2}$$

It is easy to see that both additional loading and reducing slab stiffness decrease the critical crack length. ***However, additional load has a far more pronounced effect on critical crack length than surface warming.*** That is one reason why additional loading is a much more frequent contributor to instability.

Estimating the critical cut lengths during the March 4 cycle is challenging due to lack of detailed snowpack data. However, to get an idea of typical critical crack lengths for an unstable snowpack, let's consider a 4F hard 50cm thick slab with density of 162kgm-3 and elastic modulus of 1.2MPa over a SH layer with fracture energy of 0.1Jm-2 and a hard bed surface. For such a slab/weak layer combination, the critical crack length would be 24cm. If for some reason the slab becomes softer, for instance due to surface warming, and the elastic modulus reduces to 0.9MPa, the critical cut length will be about 18cm. It is hard to estimate how much input energy is needed to reduce the overall slab's elastic modulus from 1.2MPa to 0.9MPa *(figure 1)*. However, to give you an idea, on March 23, 2011, Reuter and Schweizer measured the decrease of slab's effective modulus from 1.2MPa to 0.9MPa. This change occurred after input energy of 430kJm-2. The snow temperature at 10cm below the surface on that day changed from -4.9°C to -0.2°C.

Continued on next page ➡

Workshop discussion notes from Banff, Alberta, November, 1976:

Temperature Effects
HISTORY

Avalanche Control, Forecasting, and Safety

While researching for his article, "Playing with Fire" (see page 22), Drew Hardesty stumbled across the following notes from a discussion after a paper by Norm Wilson:

Ron Perla, the conference organizer, remembers the discussion: "Norm Wilson's presentation managed to stir up the pot; it was a small group in those days, just over 100 in a small classroom where anybody could get to the mike quickly.

"Based on Ned Bair's research, I might not have made that comment about 'inverted storm' depositing lower density snow, and I wished I had said that the cold, initial deposition could be a weak, potential failure surface (irrespective of its density)."

Newcomb: I hope no one objects if we move on to another question. Why does a rise in temperature reduce stability?

Bradley: Snow becomes very weak as it approaches the melt point (O°C). This is quite evident in the spring.

Perla: A temperature rise during a storm could produce an inverted density profile, with a heavy dense slab resting on a loose sliding layer. A temperature rise may also correlate with an increase in precipitation intensity during a storm.

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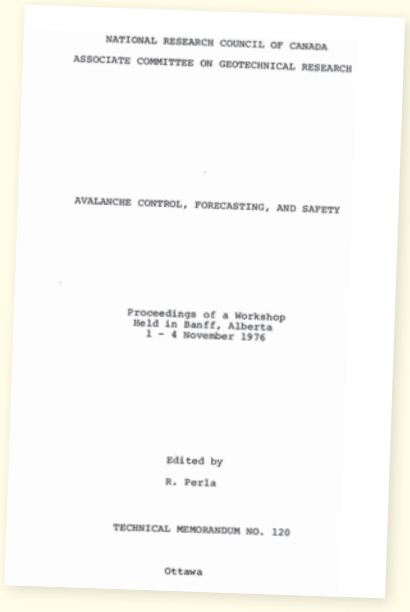
NATIONAL RESEARCH COUNCIL OF CANADA
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AVALANCHE CONTROL, FORECASTING, AND SAFETY

Proceedings of a Workshop
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Edited by
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Ottawa

TEMPERATURE OVERVIEW

continued from previous page

The missing step

Studies using fracture mechanics to model crack propagation rely on the underlying assumption that there are preexisting sub-critical flaws (cracks) where the slab is unsupported. We assume that these unsupported slab areas exist shortly before slab release occurs because the mix mode anticrack successfully predicts field observations. However, to my knowledge, there are no field observations that confirm the existence of these areas. Further, the data from Reuter and Schweizer *(2012)* suggest that if such areas exist, they have to be very close to the critical size for surface warming to cause spontaneous slab avalanche release. The critical crack length formula in combination with the results from Reuter and Schweizer *(2012)* show that under spatially consistent slabs, surface warming by itself cannot cause sub-critical cracks to expand without additional load.

However, things are different on slopes with a spatially variable slab or slopes with rocks poking above the snow surface. In such cases, free water from surface melting can percolate down to the weak layer in areas where the slab is thin or around rocks. The water can then break weak layer bonds over an area large enough for spontaneous slab release.

Another scenario may be when the load on the weak layer is unevenly distributed throughout the slope due to spatially variable slab thickness. In this case, surface creep can redistribute the load over the weak layer and potentially increase the load over areas of weaker weak layer *(see figure 2 on page 29)*. In this scenario, the increase in load might reduce the critical crack length to where a small crack can start propagating spontaneously.

Clearly, these are only two possible scenarios (and there are certainly others) and not an attempt to explain what happened under the slab in the Wasatch on March 4, 2012.

Conclusion

Regardless of the mechanisms that lead to surface warming-induced dry-slab avalanches, it is important to remember that conditions must be on the verge of instability in the first place for surface warming to make a difference. In reality, our best data and models all predict that surface warming has a real, but very small, effect on dry-snow avalanching. In other words: if you are worried that a slope will become unstable (with dry-slab avalanches) in the afternoon due to surface warming, you probably shouldn't ski or ride it in the morning! Further, if you skied a slope in the morning and it avalanched (dry slab) in the afternoon due to surface warming, you probably had a lucky morning and not a set of fine-tuned forecasting skills.

Acknowledgments

I would like to thank Alec van Herwijnen, Benjamin Reuter, Karl Birkland, and Doug Chabot for the insightful discussions over this topic and for taking the time to make sure the content of this article is, for most part, in par with current knowledge and understanding rather than the author's vivid imagination.

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Ron Simenhois has been a consistent and gracious contributor to TAR since he was a ski patroller at Copper Mountain.

PNW BOUNDARY POLICIES

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First of all, to leave or re-enter the ski area, everyone is required to have the following: beacon, shovel, partner, and knowledge of 1) the current Northwest Weather and Avalanche Center forecast, 2) that season's snowpack profile, 3) avalanche phenomena, 4) the current weather forecast, and 5) the most recent snowfall amount and type. At times Baker requires these things just to ride certain chairs!

Baker uses rope lines, signage, and access gates to manage its boundary. There are closed areas, "Extreme Danger Zones," and "Hazard Advisory Rope Lines." The result is that there are some areas you must access through gates, which may be open or closed, some areas that are roped off but it's acceptable to duck the rope, and some areas that are roped off but the ropes can't be ducked. Undoubtedly the rope lines have prevented many opportunities for the Mt Baker Ski Patrol to practice their high-angle rescue skills.

THE FOREST SERVICE PERSPECTIVE

Every ski area in this survey, and many of the other ones in the Pacific Northwest, operates almost entirely on Forest Service (FS) land. This fact makes the FS a very important entity in the discussion of how access to the backcountry will be managed. The official documents that outline policy for the FS are the FS Manual and the FS Handbook. These are documents that outline national policy, with some regions creating their own supplements that further define policy in their region.

The Pacific Northwest (region 6) does not have a specific boundary management policy to supplement the more generic national policy. The requirement outlined by the FS Manual/Handbook is that ski areas address boundary management in their annual operating plan. The example that is often cited of a region where policy has been more rigorously defined is that of Region 2, which includes Colorado. A review of Region 2's supplement shows a number of additional guidelines including: location and nature of backcountry access gates (they must be positioned so that users must physically stop and/or climb uphill for backcountry access), positioning of signage at all ingress and egress points, verbiage to be used on signs, and allowing for FS-enacted closures to restrict access into extreme avalanche hazard zones. Ski areas in Colorado are further supported in closing their boundaries by the Colorado Skier Safety Act, which allows for monetary penalties and/or jail time if closures are violated. Washington state recently (in 2011) passed similar legislation that made skiing into "closed areas" (as defined by the ski-area operator) a misdemeanor punishable by a fine up to $1000 and/or 90 days in jail.

For those who desire less government interference in our lives, this issue is a bright spot. There does not appear to be any desire by the FS to restrict access to public lands. The supplements that have been created in various regions generally encourage ski-area operators to allow access to the backcountry. The points they stress are primarily concerned with clear signage in appropriate locations. While the national policy and the supplements allow for FS supervisors to close areas of National Forest due to extreme avalanche hazard, it is generally discouraged because enforcement would necessitate qualified FS personnel who are seldom available to stand at a boundary line during a storm.

SO NOW WHAT?

When I initially began to research this issue, I thought that at the end I would come to a grand conclusion about the best way for everyone in Washington and Oregon to consistently manage backcountry access. However, after many conversations and careful consideration of the unique characteristics of all the ski areas in this part of the world, I'm not sure it would be the best idea to treat them all the same. Topography, snowfall patterns, and proximity to traditional backcountry runs are all factors that vary widely across this

Mt Baker: this sign seems pretty straightforward.

region. The policies in place at the various ski areas are what they are because that's what works best for them. Fortunately ski-area operators have been allowed to adapt and evolve because of the absence of a unilateral policy.

The issue that I described in the first paragraph still remains. If all the policies are different, how do we communicate that? First and foremost, it is absolutely the responsibility of the user to know the law of the land. If we're going to assume that they are savvy enough to check the avalanche-hazard forecast before they go into the backcountry, we should also assume they are able to look up the policy wherever they are riding.

Okay, well, we all know that doesn't always happen. As much as I'd like to be a hard ass and say, "Screw 'em, if they want to go die that's their prerogative," I would prefer not to have people get in trouble in the first place. If one thing we can do is make it easier for the backcountry users to get the information, then maybe that's something we should do.

A common theme that emerged while discussing this issue with industry leaders has been the concept of consistent signage in the Pacific Northwest. One thing that all the ski areas have in common is that those who do allow access have signage at the common access points. The verbiage and appearance of signage is a topic addressed in many of the FS supplemental boundary management plans. Perhaps coming up with a message we want to convey to all backcountry users in the Pacific Northwest, maybe even that day's hazard forecast, would become recognizable and useful to users who travel to different areas.

I have no delusions that there is a single solution to avalanche accidents in lift- accessed backcountry. They will continue to happen. Airbags, beacons that do your trig homework, and helmet-mounted cameras can't stop that. Something that we as a community do believe is that education and intentional decision-making do help. So if there is a way to make that process front and center, I think we should do it.

A Pacific Northwest native, Dan grew up skiing and climbing in the Cascades. His love of being in the mountains has taken him on expeditions all over the world. Dan has worked as a professional ski patroller at Stevens Pass for the past six years, and as an National Park Service climbing ranger at Mt Rainier National Park. Dan is an EMT and an AIARE 1 instructor.

SURFACE WARMING

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over a much wider area than, say, a skier. However, for the perturbation to have an effect, the existence of a critical slab/weak layer combination is probably essential *(e.g., Exner, 2013)*.

We now look at the two processes of failure initiation and crack propagation. In the case of natural release, failure initiation from damage accumulation (i.e., sub-critical crack growth) is due to the increased deformation in the topmost slab layers. This will increase the strain rate even down at the depth of the weak layer, though warming has not reached the weak layer. This can be shown, for instance, by finite-element (FE) modeling *(Habermann, et al., 2008)*. As snow strength is rate-sensitive, it seems plausible that surface warming may – where snow conditions are critical – lead to an initial failure.

In the case of human triggering, failure initiation is due to the localized dynamic load by the over-snow traveler. Measurements of the person's impact indicate that the stress at the depth of the weak layer increases when the surface layers are relatively warm and cohesive *(Camponovo and Schweizer, 1997; Exner and Jamieson, 2008; Schweizer, et al., 1995)*, which is in agreement with FE modeling *(Wilson, et al., 1999)*. Again, failure initiation is thought to become more likely due to changes in slab properties.

For crack propagation, the question is how surface warming affects the energy release rate. Reuter and Schweizer *(2012)* have recently conducted series of field measurements on days when surface warming was anticipated. They performed propagation saw test measurements *(Gauthier and Jamieson, 2006)* and were able to show by means of FE modeling that the specific fracture energy – a material property that is a measure of toughness (resistance to crack propagation) – remained unaffected. Measurements on the fracture toughness in tension with cantilever-beam experiments in the cold lab indicated that the fracture toughness decreases with increasing temperature up to about 8°C (with increased scatter suggesting an increase of toughness toward the melting point) *(Schweizer, et al., 2004)*.

As the slab stiffness decreases, the energy release rate should increase so that shorter critical crack lengths result (assuming that the specific fracture energy of the weak layer remains unaffected) – equivalent to higher crack propagation propensity. In their field study Reuter and Schweizer *(2012)* observed a slight but significant trend toward shorter cut lengths when the effective modulus of near-surface slab layers had decreased *(see Figure 3)*.

Furthermore, FE modeling indicates that the energy release rate depends strongly on the properties of the lower slab layers, which are rarely affected by daytime warming. For example, if the weak layer is overlain by a crust, the effect on the energy release rate is small when surface warming softens the upper layers. This finding suggests that surface warming is most efficient in the case of relatively thin new snow slabs (usually less than 50cm) *(McClung and Schaerer, 2006, p. 97)* – in agreement with observations by experienced practitioners.

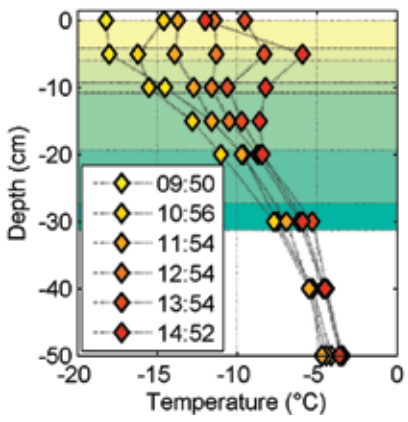

Figure 1: Snow temperature profiles (diamonds) measured on a southwest-facing slope on March 8, 2010. Yellow to green areas denote slab layers.

While there are fascinating examples of deep-slab natural avalanches during warming, a causal effect cannot be explained by current theory. Even in hindsight, not all avalanches have an identifiable trigger.

CONCLUSIONS

We have revisited the effect of surface warming on dry-snow slab release. Whereas the effect of warming to 0°C (surface becomes moist or wet) on loose-snow avalanching is strong, the effects we discuss on dry-snow slab release seem subtle. Without certain preconditioning, e.g., specific stratigraphy of the snowpack, surface warming will probably not cause instability.

Instability always stems from changes in slab properties. Increased deformation due to reduced stiffness of the surface layers increases the strain rate in the weak layer, increases the energy release rate, or increases the skier stress at depth. All these effects are immediate and promote instability (whereas delayed warming effects tend to promote stability) *(McClung and Schweizer, 1999)*. Surface warming is most efficient with warming by solar radiation as radiation penetrates the surface layers where the energy is released. Surface warming due to warm (relative to the snow surface) air temperatures is a secondary effect – except in the case when a moderate or strong wind blows.

When doing field tests such as the PST, shorter crack lengths were observed with surface warming. So far, evidence is rare; Reuter and Schweizer *(2012)* provide the first field study physically linking surface warming to dry-snow instability.

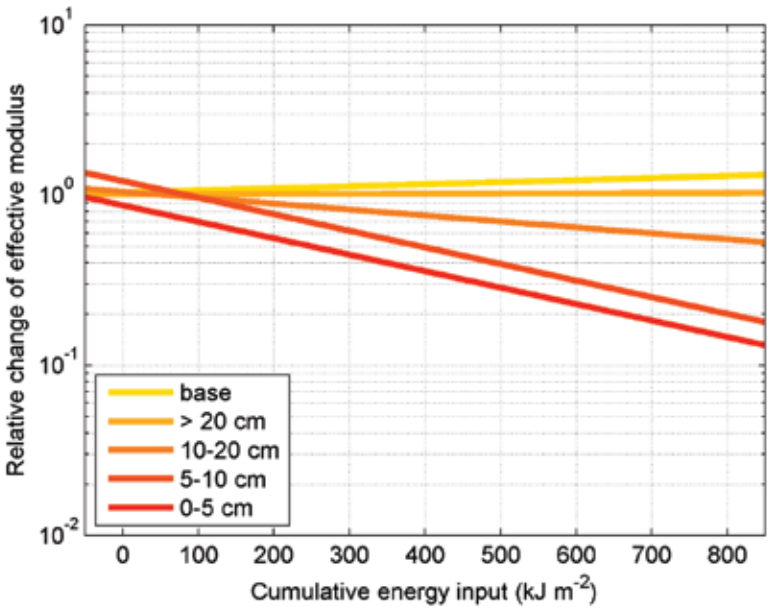

Figure 2: Trend lines for the relative change of effective modulus in a given range of depth vs. cumulative energy input at the snow surface. The closer a layer is to the surface the more pronounced is the change in slab stiffness with increasing energy input into the snowpack.

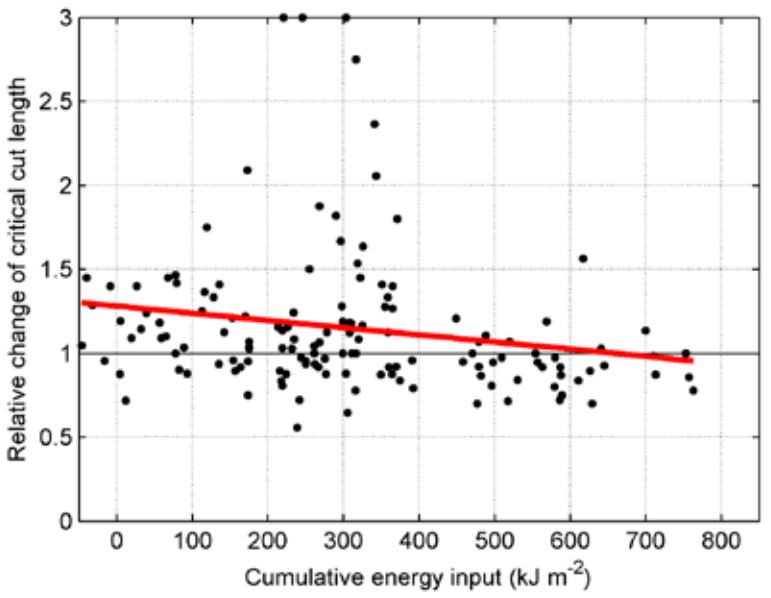

Figure 3: Relative change of critical cut length vs. cumulative energy input at the snow surface: There was a slight but statistically significant trend to shorter cut lengths with increasing energy input into the snowpack. *Figs 2 & 3 reproduced from Reuter & Schweizer (2012) with permission from Elsevier*

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Field measurements on the fracture behavior of snow: performing series of PST in the course of a day and concurrently measuring slab stiffness with the SMP.

Photo courtesy Jürg Schweizer

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COOLING AVALANCHES

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Common factors in the events of 2010/11:

- Heavy storm loading occurred prior to the event.
- All but one failed on a Persistent Weak Layer.
- Rapid air temperature cooling occurred, often around 7-10° C overnight.
- They were mostly very large events with wide propagation.
- In every case, experienced locals were surprised by the events.

IN CONCLUSION

So what does all this mean? Is there more to take away than a vague sense of paranoia?

It seems clear that avalanches sometimes occur during periods of rapid cooling, both when the snow surface is going from melt to freeze and at overall colder temperatures. It is unclear whether, or how, cooling itself triggers avalanches – and that is a topic for a whole different study. What does seem apparent to me is that many near-misses and possibly some serious accidents were caused by faulty decision-making around cooling. The premise that cooling stabilizes the snowpack after the end of a storm (or solar warming) is not always correct. Always basing decision-making on this premise can lead to premature exposure of people to avalanche terrain.

The most constant element in these events was that of surprise. In many cases, professionals were just about to (or just had) opened terrain previously off-limits for public, guest, and staff access.

This research is mostly a collection of anecdotes. In order to really understand the mechanisms behind avalanches that occur during periods of cooling (and from there, to be able to forecast them), as a community we need to better document this type of event. I hope this preliminary investigation will spark some discussion, spawn some more focused research, and perhaps encourage decision-makers to take a second look at conditions during periods of rapid cooling.

I presented this topic at conferences in Penticton, BC, and New Zealand last year. On both occasions, numerous audience members revealed that they, too, had experienced surprising avalanches during times of rapid cooling. My feeling is that this phenomenon, while sporadic, is more common than one might expect.

ACKNOWLEDGEMENTS

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Penny Goddard is an avalanche forecaster, educator, author, ski patroller, mountaineer, and mom of a now-seven-month-old daughter.

HISTORIC DISCUSSION

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Wilson: In my paper, I was not referring to spring conditions, or to a temperature rise during a storm, but to a sudden rise in temperature on a clear winter day, when the snowpack temperatures are below O°C.

McClung: The near-surface snow layers will deform more rapidly at warmer temperatures.

Newcomb: But how does one explain deep-slab instability with this mechanism? Snow is a good insulator, and conducts heat slowly. Perhaps a sudden temperature rise affects the surface, but what does this have to do with deep-slab instability?

Williams: Also, Norm Wilson mentioned that a sudden drop in temperature may also decrease stability.

Wilson: I reluctantly included that remark in my presentation. However, a number of the people I work with believe that any sudden temperature change, rise or fall, decreases stability.

Wakabayashi: A temperature change, rise or fall, could lead to changes in surface tensions and differential contractions or expansions.

Lev: At Alta, we have also been concerned about all sudden changes in the stress state of the snowpack. Snow Ranger Bings Sandhal is presently measuring the effects of barometric pressure changes as well as temperature changes. One must keep in mind that the snowpack fails due to stress changes that are quite low (~10mb).

Armstrong: Granted that sudden air temperature changes affect the snow surface, but, as Rod Newcomb previously noted, snow is a poor conductor of heat. Therefore, how is a rapid change in air temperature transmitted to any significant depth?

LaChapelle: Indeed, heat is conducted slowly, but mechanical disturbances (fracture, stress waves) propagate quickly. If the temperature change leads to a mechanical change at the surface, then perhaps it is the mechanical disturbance that propagates to depth.

Wilson: I hope I did not leave the impression that sudden temperature change is the most important variable in deep-slab instability. It may only be the "straw that broke the camel's back."

Speakers: Rod Newcomb, Russ Bradley (W.R. Bradley, a Canadian avalanche pioneer, not to be confused with US pioneer Charlie Bradley), Ron Perla, Norm Wilson, Dave McClung, Knox Williams, Ryuzo Wakabayashi, Peter Lev, Richard Armstrong, Ed LaChapelle. The original typed text of this discussion can be found at http://arc.lib.montana.edu/snow-science/objects/issw-1976-073-076.pdf