37.1
OCTOBER 2018

THE AVALANCHE REVIEW

Photo by
Andy Nassetta

Bo Torrey, Utah Avalanche Center (UAC) Program Manager, investigates a snowmobile-triggered avalanche that happened on March 10 in First Cornice Bowl in the Guardsman Pass area of the Central Wasatch Range. The first snowmobiler triggered the slide as he rode over a thin spot at the top of the slope while the second spotted from below. Neither sledder was caught, and they quickly established communication via radio with one another and then reported the slide to the UAC.

Read more season stories on page 30.

201718 season stories

Highland Bowl
34 years ago, a monumental avalanche wrote a tragic chapter
Page 18

We F*#%ed Up
A near miss reinforces the importance of the double-check
Page 24

THE AVALANCHE REVIEW

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AMERICAN AVALANCHE ASSOCIATION

A3 STATEMENT OF PURPOSE

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

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Articles, including editorials, appearing in *The Avalanche Review* reflect the individual views of the authors and not the official points of view adopted by A3 or the organizations with which the authors are affiliated unless otherwise stated.

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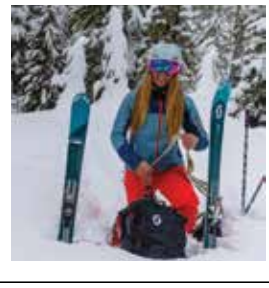
Mike Town's career in geoscience includes a Ph.D. in Atmospheric Sciences from the University of Washington, and field work in rural Michigan, the Arctic, the Swiss Alps, and a winter at South Pole Station, Antarctica. He has taught in public and independent high schools since 2011. He currently teaches at Lakeside Upper School, an independent high school in Seattle, WA. He enjoys hiking, skiing, martial arts, and spending time with his family: Shelley, Niko, and Socks.

Tim Cooney is an Aspen-based freelance writer and semi-retired Aspen Mountain ski patroller. He writes about Aspen history for Aspen Journalism, a nonprofit organization that supports in-depth reporting in the public interest, in collaboration with the *Aspen Daily News*. More at aspenjournalism.org.

Grant Gunderson founded *The Ski Journal* where he served as photo editor for over six years. He has shot for every major snow sports and outdoor publications worldwide including *ESPN, Outside, FHM, Backcountry, Aka Skidor, Fri Flyt, Skiing*, and *Kootenay Mountain Culture*. He currently serves as a senior photographer for *Powder Magazine* and field editor of *The Ski Journal*. He skis close to 200 days a year and when he is not on snow you can find him on his bike or trekking throughout North America and beyond.



Kirsten Rowley is a firefighter and outdoor adventurer from the Hood River area that loves to ski and mountain bike. At press time she was working a fire deep in the wilds of British Columbia, but she was adamant that this story be told, and insistent on the importance of questioning our partners on protocols and plans.

FROM THE EDITOR

BY LYNNE WOLFE

Photo Leslie Hittmeier

First issue of the upcoming winter is always dedicated to looking back at the previous one. When Wendy Wagner and I were planning our campaign to solicit season summaries from all the avalanche centers, we worked to craft a question that would fit the wide variety of winters that everyone experienced. Here's what we came up with:

What was the biggest challenge or question for your avalanche center this year?

I've learned a lot from carefully reading this year's submissions. Patterns of weather, persistent weak layers, storms, and the subsequent stability fluctuations become clearer when we can look at the whole season. This year the essential specific question debated in a number of avalanche centers was when to drop the stability rating a notch, especially when dealing with a persistent weak layer, of which there were many. Several season stories address this particular question directly. Have a look at the NWAC (page 35), the Flathead (page 33) and the Chugach (page 44) for good examples. In addition, here in the Tetons we found Jason Konigsberg's article from TAR 36.3, (Feb 2018) Trends of Persistent Slab Avalanches after Snowfall, to be an excellent resource. I love understanding the rhythms of a snowpack and making better decisions accordingly. I strongly believe that paying attention to last year's patterns will help me recognize subtleties as they arise in this year's progression.

I was also struck by how certain persistent weak layers (the DDL, or December drought layer, discussed in TAR 36.4) revived in the spring with the presence of free water from rain or when there were two or three non-freezing nights. We'll be pursuing advances in wet snow research and forecasting in the February TAR, 37.3. Deadline for submissions for that one is December 15, if you have thoughts, questions, or experience around the wet snow topic.

In addition to the season's stories, in this issue you will find a fabulous in-depth look at an avalanche that took place in 1984 in the ski area Aspen Highlands' renowned Highland Bowl (page 18). Author Tim Cooney did some in-depth reporting and TAR is gratified that the Aspen Times allowed us to reprint their story.

If you're looking for inspiration as an educator, check out Mike Town's story about his work with high school students on page 14. I sure wish my high school science went to that depth, and was that much fun.

If you're planning to teach or to take a Pro level class this winter, you'll want to read Peter Earle's recap of his experience last winter teaching Pro courses. His list of suggestions for incoming students is right on the money.

Acclaimed outdoor photographer Grant Gunderson shares an amazing image of a near-miss about which he and his skier Kirsten Rowley penned very self-aware critiques. You can find their "mea culpa" on pages 24-28.

Finally, a musing on community. In 2018 I have leaned harder on my community than ever before. My Teton friends, my avalanche colleagues, my family have all given me incredible energy to regain health and vitality. I'm on my way. Thanks to all of you who wrote notes and sent good wishes (and salmon, so much yummy salmon). Much appreciated. We could all use that level of support at some point, I would venture.

I will miss being part of the ISSW community this year, but I've recruited an army of TAR scouts to note what strikes them as new or important to their practice, or makes them think in a different way about an avalanche phenomenon. Look for their reports in the December TAR. ▲

2018/19 REGIONAL SNOW AND AVALANCHE WORKSHOPS

OCTOBER 5: Colorado SAW – Breckenridge, CO
OCTOBER 20: California AW – Kings Beach, CA – North Tahoe Events Center
OCTOBER 26: Utah SAW – Sandy, UT – Mountain America Expo Center
OCTOBER 27: Wyoming SAW – Jackson, WY – Center for the Arts
OCTOBER 27: Northwest SAW – Seattle, WA – The Mountaineers
NOVEMBER 3: Eastern SAW – Fryeburg, ME – Fryeburg Academy
NOVEMBER 3: Northern Rockies SAW – Whitefish, MT – O'Shaughnessy Center
NOVEMBER 9: Southcentral Alaska Avalanche Workshop – Anchorage, AK – Alaska Pacific University
NOVEMBER 10: Bend SAW – Bend, OR – Central Oregon Community College
NOVEMBER 26: MSU SAW – Bozeman, MT – Montana State University

Spring 2019 Sawtooth SAW – Ketchum, ID – Whiskey Jacques
April 2019 Gallatin Professional Development Seminar – Bozeman, MT – Bozeman Public Library

Visit the A3 website for more information on these workshops.

October 07-12 ISSW 2018 INNSBRUCK

A3 is pleased to again serve as a Supporting Sponsor for the ISSW (International Snow Science Workshop), which this year will be held October 7-12 in Innsbruck, Austria. The ISSW is the world's largest conference on snow and avalanches. About 1,000 participants are expected to gather to focus on current advances in snow and avalanche science, case studies, and innovative technologies from international and interdisciplinary perspectives.

In addition to our sponsorship of this important conference, **A3 is supporting two scholarships** for A3 members to attend. Each scholarship includes a free conference registration and a $500 stipend to defray travel expenses. Scholarship recipients will update us from the conference itself and in articles for upcoming issues of *The Avalanche Review*. Our thanks to all our members and corporate sponsors for making it possible for us to participate in this way in the ISSW.

Incoming A3 Executive Director Dan Kaveney will be hosting an A3 table at the conference. He hopes all of you who are attending will stop by and introduce yourself and discuss all things avalanche and A3! ▲

AMERICAN AVALANCHE ASSOCIATION

TAR THEMES AND ROLLING DEADLINES FOR SUBMISSIONS:

37.2: December 2018 due Oct 1–15
Theme: what's interesting from ISSW

37.3: February 2019 due Dec 1–15
Themes: wet snow and revisiting the DDL

37.4: April 2019 due Feb 1–15
Themes: human factors and decision-making, with an emphasis on resilience

FROM THE EXECUTIVE DIRECTOR

BY DAN KAVENEY

I'm delighted to be writing my premiere column for *The Avalanche Review*. Thank you for your warm welcomes, supportive messages, and offers of help. My first couple of months have been a whirlwind of activity as I've worked to understand the A3 ecosystem: our members, sponsors, partner organizations, board, and staff. You've all been remarkably helpful, uplifting, and inclusive. I'm grateful, and am very much looking forward to getting to know you as we guide A3 toward a future we all want.

My first order of business is to thank outgoing Executive Director Jaime Musnicki for a job very well done. Jaime was a terrific Executive Director who guided A3 to some remarkable accomplishments, among them the first season of the Pro Training program, the reorganization of the board structure, the redesign of *The Avalanche Review*, and the publication of a new volume of *The Snowy Torrents*. In addition to wielding her considerable leadership skills Jaime implemented smooth and effective administrative systems from which we all continue to benefit. It's more than a little daunting trying to fill her accomplished shoes. Please join me in thanking her for her service to A3 and wishing her well in her future endeavors. She will be missed.

I come to A3 as a lifelong skier, climber, and general mountain guy. I'm not an avalanche professional. I'm an enthusiastic recreationist who has relied on avalanche forecasts and avalanche control activities to enjoy many great days in the mountains. Avalanches, avalanche education, and the labors of avalanche professionals have been instrumental to my life, and I'm looking forward to the prospect of giving back to a profession that has given a lot to me. Prior to A3 I worked as a publisher where I spent most of my time engaged in the Earth Sciences and engineering. At first blush this line of work may seem worlds apart from A3, but I see more similarities than differences. Both publishers and A3 use physical science, education, and outreach to effect positive change in the world, and I'm finding many of my activities as A3 Executive Director resonate strongly with my former work. I hope to use the experiences gained as a publisher to continue to build on A3's positive trajectory and many past successes.

So what's next for A3? I've been consulting with the Board and as many members as possible in an effort to define our path forward. Foundationally, everyone wants to continue to grow our influence by effectively fulfilling our mission and serving our members. In order to do so we need to continue to expand our reach while simultaneously grounding ourselves on a firmer financial footing. We can begin with a few key activities:

- Expand our membership. Continue to persuade more practicing and aspiring pros to join our ranks, and recruit more enthusiastic recreationists to join as Subscribers. The more members we have, the more effectively we can serve our mission.
- Expand, tighten, and increase the productivity of our relationships with corporate sponsors. Members and sponsors are the lifeblood of A3. We'll be better off if we can work more effectively with the sponsors we have and recruit new sponsors to the organization.
- Continue our focus on strong publishing. *The Avalanche Review* is a very important part of A3, as are *The Snowy Torrents*, *Snow Weather and Avalanche Guidelines*, and our other publishing endeavors. We need to maintain these publications, work more aggressively on digital publishing, and identify additional publications that could help with outreach.
- Stay focused on the Pro Training Program, which is now entering its second season, especially with respect to supporting the six Pro Training Providers.
- Expand our outreach activities by continuing and expanding our partnership with the National Avalanche Center on avalanche.org, continuing to offer grants to the regional Snow and Avalanche Workshops, maintaining and expanding our scholarship and research grant programs, and by increasing the effectiveness of our communication with recreationists.

I'm a collaborative person so I'm very interested in learning your ideas about how to move the organization forward. I'll be attending the ISSW and as many SAWs as I can. I look forward to meeting as many of you as possible at those venues. In the meantime I can be reached at dan@avalanche.org, at 307.264.5924, or at PO Box 7019, Bozeman, MT 59771. I hope you'll be in touch. ▲

DR. ED ADAMS: A3 HONORARY MEMBERSHIP

BY HALSTED MORRIS, VICE PRESIDENT AND CHAIR OF THE A3 AWARDS AND MEMORIAL COMMITTEE

Honorary Membership is the highest award that the American Avalanche Association has; the award recognizes those with long careers of accomplishments in the North American avalanche community. Anyone that has attended an ISSW can attest to the quality of Dr. Ed Adams's presentations and the scope of his research work. With his retirement from Montana State University this past May, it seemed most appropriate to present his Honorary Membership award at the Gallatin Professional Development Seminar. Ed was nominated for the award by Daniel Miller of the USGS, Karl Birkeland of the NAC; Doug Chabot of the Gallatin NF Avalanche Center, Kevin Hammonds of MSU, and Doug Richmond from Bridger Bowl. Below is the award citation.

"Dr Ed Adams has studied snow and avalanches for more than 25 years. He is an internationally recognized expert in snow/ice mechanics and is a faculty member of the Civil Engineering Department at Montana State University. He has participated in cold regions research on several continents and in several countries including: US, Canada, Switzerland, Japan, France, India, Russia, Norway, Italy, Germany and Antarctica. While he has studied many aspects of snow and ice, his true expertise is in snow microstructure. The very small ice grains and their interconnecting bonds are the building blocks determining most snow properties and responses, such as avalanches. These building blocks are in a constant state of change making them especially challenging to study.

Ed has more than 85 publications and nearly 100 presentations in the area of snow/ice mechanics and avalanches. His avalanche work has been highlighted in many public venues including the *New York Times, Good Morning America, ABC World News Tonight*, the *Discovery Channel*, *National Geographic Adventure Magazine, People Magazine*, and the *Chicago Museum of Science and Industry*, just to name a few.

One real strength of Ed's research is how it bridges the gap between theory and practice. While his ties to the research community are strong, his relationship with the avalanche safety profession is equally strong. He is a professional member of the American Avalanche Association and has long served on the steering committee of the International Snow Science Workshop. The primary aim of this workshop is merging theory and practice on an international stage. Ed has been a consistent leader in that venue. Ed's research is a wonderful blend of field, lab and theoretical work contributing to the fundamentals of snow science supporting practical application in relevant avalanche safety professions."

On behalf of the American Avalanche Association we congratulate Ed on his Honorary Membership. ▲

Top: Ed's award, created by Kiitellä. To see more work by Kiitellä, visit www.kiitella.com.

Bottom: Below: Several of Ed Adams' award nominees were present to honor him at the Gallatin Snow and Avalanche Workshop in March of 2018. From left to right: Dan Miller of the USGS, Karl Birkeland of the NAC, Ed Adams, and Doug Chabot of the Gallatin NF Avalanche Center. *Photo Jaime Musnicki*

WSDOT M60 TANK

Was it for this my life I sought?*

BY JOHN STIMBERIS

*(Phish—Stash)

When I started my highway career at the WSDOT I arrived with some artillery experience. My experience was quite limited though, as Alpental Ski Area relied heavily on ANFO, hand charges, and ski cutting to get the job done, and the 75mm recoilless was occasionally used. The highway program also relied on ANFO, but a few hard-to-reach areas required artillery. Highway work differs a bit from ski area work, mainly that it is a 24/7 operation, but also the snow quality following control work doesn't matter like it does for ski slopes. The highway worker's aim leans more towards destroying the snowpack than simply making it safe and enjoyable. Thus we tend to hit the slopes a bit harder

The WSDOT South Central Region program I joined used a 105mm recoilless at that time. It has a bigger round than the 75mm, but still small stuff compared to 25 lb. bags of ANFO. Our program in the North Central Region relied a bit more on artillery, and the manager at the time had a strong interest in artillery. He also made some unique connections with the military, whose program had a 105mm howitzer (now the standard) and also several surplus M60 tanks. Yes, M60 battle tanks, fully operational! I was more than a little excited about the possibility that I might get to drive a tank when our yearly artillery training came around.

Back in those days our live fire artillery training took place outside Yakima, WA, at an Army training center. Rolling hills of sage and bunch grasses were a world away from steep mountains of snow, but the old helicopters, personnel carriers, and other targets were pretty cool. My first year I volunteered (several times) to drive the tank to the appointed range for the refresher. I didn't have too much competition though, and later learned why. The 30-ish mile roundtrip to the range is a bit of a drive in the tank. As fun as it looks and sounds, driving the tank loses its charm after a few miles. That charm tarnishes even further if the weather is less than ideal.

During those years the North Central crew used the tank and howitzer for artillery avalanche work on Stevens Pass and North Cascades Highway, while the South Central crew still relied on the 105mm recoilless. The recoilless program was doomed though. Aging weaponry and ammunition, plus a couple accidents with the 106mm recoilless, led us to the need to fire from a protected spot. For our program that meant ascending and descending a 35-foot tower for every shot. Just the firing phase of an artillery mission could take up to three hours. Closure times like that aren't favored for a major interstate highway like I-90.

Photo: B. Pritchett

Our program constructed a suitable placement on Dodge Ridge just above the Summit West Ski area and down the ridge from our recoilless tower. We hired a lowboy and transported the 60-ton training tank from the firing range to Snoqualmie Pass. The question I often get is "How did you get it to the top of the ski area?" and the day we moved it up the hill my manager asked the same question. The answer was simple; "I'm gonna drive it there!"

I don't think I've seen any less confident looks in my life. But away we went. Most of the drive up the hill was fairly straightforward. A summer road leads to the communication site at the top of the ridge. Just before the top I had to make a turn onto our newly constructed road for the last few hundred feet to the tank pad. Here we encountered the tricky part. I needed to turn the tank around to be oriented correctly on the pad and there wasn't room to do it at the pad. I turned the tank and backed in the last few hundred feet with the aid of several spotters. You really can't see much driving a tank forward. In reverse it's all up to the spotters!

Once installed and with our targeting completed we were in business. The tank blew away the recoilless (not literally). Artillery missions can take an enormous amount of time both pre- and post firing, but the firing part is what most people experience. Those long recoilless missions were over. We were now completing the firing in 30-45 minutes. The advantages were realized in many areas. The impacts on the highway were reduced as were the impacts on the neighboring ski areas. With the recoilless we had to close Summit West Ski Area due to the back blast from the recoilless and Alpental due to shrapnel hazard. With the tank we didn't need to close Summit West and the impacts to Alpental were often reduced to 15 minutes. The improvement in time also led to better timing in relation to snow instability. If you've ever forecasted or controlled in a maritime climate, particularly one that experiences rain like we do, then you understand that peak instability can come and go rapidly. We often lost our window of instability during a recoilless mission, but with the tank were getting better results.

One of the most unique advantages of the tank is that the rounds are in the turret with the gunner and loader. Loading is also quite simple, thus an experienced crew can move along quickly, safely, and efficiently. You're also contained inside the tank which makes an artillery mission quite pleasant when it's raining 0.30"/hr. I'll never miss those missions on the recoilless tower in the driving rain and 50 mph winds!

If you would like more information about the M60 tank and M101 howitzer check out Marty Schmoker and Mike Stanford's paper from the 1996 ISSW. These guys provide a great overview of the systems and how the two weapons became viable tools for artillery-based avalanche hazard reduction.

There's one main problem with artillery and that's time. The weapons and ammunition we use are surplus and getting older every year. Their days of usefulness to the military have come and gone. Availability of ammunition is one thing, the other is the knowledge base of those trained and experienced with maintaining these weapons. The Army was no longer able to provide reliable maintenance for the M60 as those trained to do so have mostly retired. We're fortunate to have some very qualified howitzer personnel around, but they won't be here forever.

Eventually the time came to end the M60 program and this past June I drove the tank off the hill. I was fortunate to be part of two recoilless programs, but those days have come and gone and the recoilless is over. I am quite grateful to have been part of the M60 tank program. It was a very unique chapter in North American avalanche artillery use. I've also been part of the howitzer program for many years and have seen some very good improvements and changes to the overall artillery program in this country during that time. I'll definitely miss the tank, but I won't hesitate to embrace the howitzer program for what it is: an opportunity to look to the future. The howitzer is aging and will eventually need to be replaced, and I'm taking this opportunity to find a new way to protect I-90 from avalanches. The solution will most likely involve a combination of physical protection and remote avalanche control devises. Once we find the solution it will probably be the end of artillery for our pass. ▲

John Stimberis is the Highway Forecast Supervisor for the South Central Region of the WSDOT and current Vice-Chair of The AAUNAC. John is also wrapping up his final term as President of the American Avalanche Association. When John isn't creating avalanches with his skis or explosives you can find him enjoying live music, running, and sampling fine IPAs in his home of Seattle.

The tank appears large from the outside, but there really isn't much room inside. We operated with a loader and gunner in the tank and an observer outside the tank. During the firing mission the loader and gunner are on either side of the breech when the weapon is fired. Imagine that large round being detonated a few inches from your head!

SAWTOOTH AVALANCHE CENTER CHANGES

BY SCOTT SAVAGE, SAWTOOTH AVALANCHE CENTER DIRECTOR

Matt Wieland moved on from his Avalanche Specialist/Forecaster position this past April. Matt brought a rare combination of skills and experience to the USDA FS Sawtooth Avalanche Center (SAC): nearly a decade of active mitigation work, an advanced degree in the field, a lifelong love for machines that burn oil, expert riding ability, a solid understanding of remote weather stations, impressive fabrication and digital photography skills, mechanical aptitude...the list goes on. Matt's ability to wear many hats at once to simply "get things done" will be sorely missed—he is truly a modern renaissance man. We wish Matt the best of luck going forward. He plans to continue working with both the SAC and the Friends of the SAC in some capacity in the future.

The SAC is thrilled to introduce—or reintroduce—the newest SAC full time forecasting team member: **Chris Lundy**. Chris has 15 years of avalanche forecasting experience and worked at the Sawtooth Avalanche Center from 2004-2012, including two years as the Director of the SAC. Chris left the SAC in 2012 to pursue other interests in the snow and avalanche world, but he's eager to return to the 'hot seat.' Chris is "excited to return to avalanche forecasting and to re-join the dedicated Sawtooth Avalanche Center team. There have been many positive changes since I left and I look forward to helping advance the SAC's critical public safety mission." We're absolutely thrilled that Chris chose to circle back to why he initially became interested in snow and avalanches: regional backcountry forecasting.

Thanks to a generous local individual, the SAC is also adding **Ben VandenBos** as a part-time fourth forecaster. Ben worked as an intern at the SAC the past two winters, has thousands of days of backcountry experience under his belt, and brings impressive digital photography and GIS skills to the team. Hiring Ben allows the SAC to add popular ski and snowmobile terrain on the north end of the advisory area. ▲

AVALANCHE DETECTION SYSTEMS—CHARACTERISTICS, EXPERIENCES AND LIMITATIONS

BY LISA DREIER, ROZ REYNOLDS, AND WALTER STEINKOGLER

Snow avalanches pose a hazard for people and infrastructure during the winter season. Permanent measures (tunnels, steel structures, etc.) and/or active and passive temporary measures (e.g. road closures, evacuations, preventive avalanche release, avalanche forecasting, etc.) are used to mitigate this hazard. The preventive release of snow avalanches along traffic routes is often used where permanent measures are too expensive or not feasible to construct. Reliable feedback whether an avalanche was successfully triggered makes preventive avalanche release more effective.

The application of avalanche detection systems allows for a reduction of road closure time in combination with a reduction of residual risk and aids the avalanche control team in their decision making. The knowledge of occurrence, frequency and size of avalanche events assists personnel responsible for avalanche control and forecasting.

A variety of detection systems are available and have been tested in operational use. Depending on the aim of the operation, the most suitable system should be selected (*Table 1*).

This article focuses on technical characteristics, operational experiences and the limitations of radar, infrasound and geophone systems (*Figure 1*).

RADAR SYSTEMS

Technical description

Radars have been applied for the detection of avalanches for many years. In most cases Doppler radars are used, emitting electromagnetic waves at a certain frequency, which are then reflected and travel back to the radar (Gauer et al., 2007). Thus the radar requires line-of-sight of the avalanche paths in question. The radar can discriminate between moving and static targets and therefore measures the velocity of the avalanche front.

Experience with radar

Since 2011 a long-range avalanche radar has been installed in Ischgl, Austria with the purpose of i) Verifying the controlled release of avalanches and ii) Gathering information about spontaneous avalanche activity. The radar is a standard operational tool of the safety staff (Steinkogler et al., 2018). The big advantage of the radar is the accurate detection of even small avalanche events. The shorter the distance to the radar antenna and the better the weather conditions (i.e. no rain, no snowfall), the smaller the detectable avalanches are (events of a few 100 m³ in a distance of 1.5 km were detected).

Power can be provided by fuel cells or by permanent power supply if available. Since radar systems provide data in real-time, alarm thresholds can be defined which allow using the system for the automatic closure of traffic lines.

The newest radar generation has a range of approx. 5 km. Based on the success of the avalanche radar, the short distance avalanche radar with a 500 m range and less energy consumption was developed (*Table 2*). They are mounted directly on remote avalanche control systems (RACS) to get immediate information about the success of the avalanche release. This is a much-needed feature for verification of preventively released avalanches. Last winter a short-range radar has been installed in Glacier National Park, Canada. The system detected 10 avalanche events which were triggered by the avalanche tower it was installed on as well as by the adjacent tower. Furthermore, other uses of this radar type, such as the detection of persons moving in the area endangered by avalanches, were successfully tested (Video: http://gpr.vn/PETRA).

By the end of the 2018 winter season multiple long and short-range radar systems of the newest version have been installed and successfully operated in the Alps, North and South America. These systems monitor both frequent spontaneous and controlled avalanche events.

INFRASOUND

Technical description

Infrasound waves are low frequency (<20 Hz) sound waves traveling through the air at the speed of sound. Their frequency is too low to be perceived by the human ear. The infrasound technology is widely used for the detection of different natural (e.g. volcanic eruptions) and artificial phenomena (e.g. nuclear explosion). For avalanche monitoring the infrasound technology has significantly improved in recent years in terms of sensor design, noise reduction and processing algorithms (Ulivieri et al., 2011).

Typically, an infrasound detection system consists of a 4 to 5-element infrasound array, with a triangular geometry and an aperture (maximum distance between two elements) of approximately 150 m (Marchetti et al., 2015). During the winter season, the sensors are covered with snow, which helps to dampen ambient noise. This setup allows monitoring of the avalanche activity from all directions within a radius of 3–5 km). (*Table 2*).

Experience with infrasound

To gather information on avalanche activity of a larger area and to assist the local avalanche control team an infrasound was first installed in 2012 in Ischgl, Austria. The goal was to gather information about avalanche activity from all avalanche paths in the area. The system worked very well in the first year, and in the second year the detection capabilities could even be enhanced. Based on this success additional systems were installed.

	PREVENTIVE AVALANCHE RELEASE	ALARM SYSTEMS	AVALANCHE WARNING
	Verification of blasting result	Automatic closing of traffic routes	Verification of avalanche activity
INFRASOUND	✓		✓✓
LONG-RANGE AVALANCHE RADARS	✓	✓✓	✓
SHORT-RANGE AVALANCHE RADAR	✓✓	✕	
SEISMIC SYSTEMS: SEISMOMETER, GEOPHONE	✓	✓	

Table 1: Avalanche detection systems and their suitability for different operations.

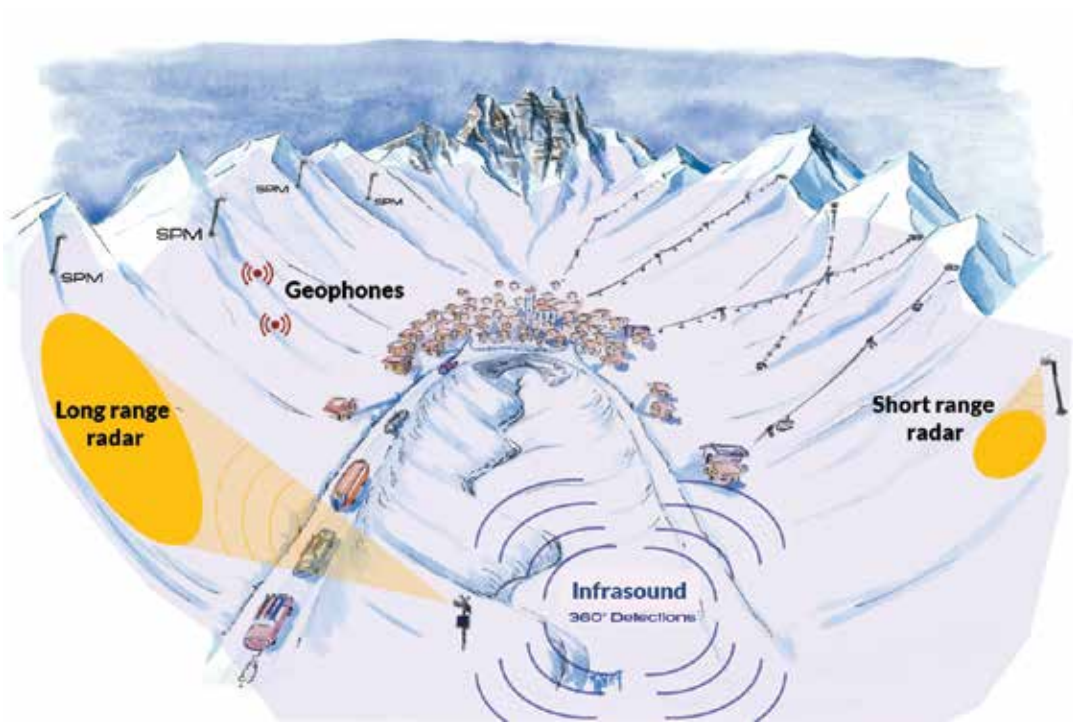
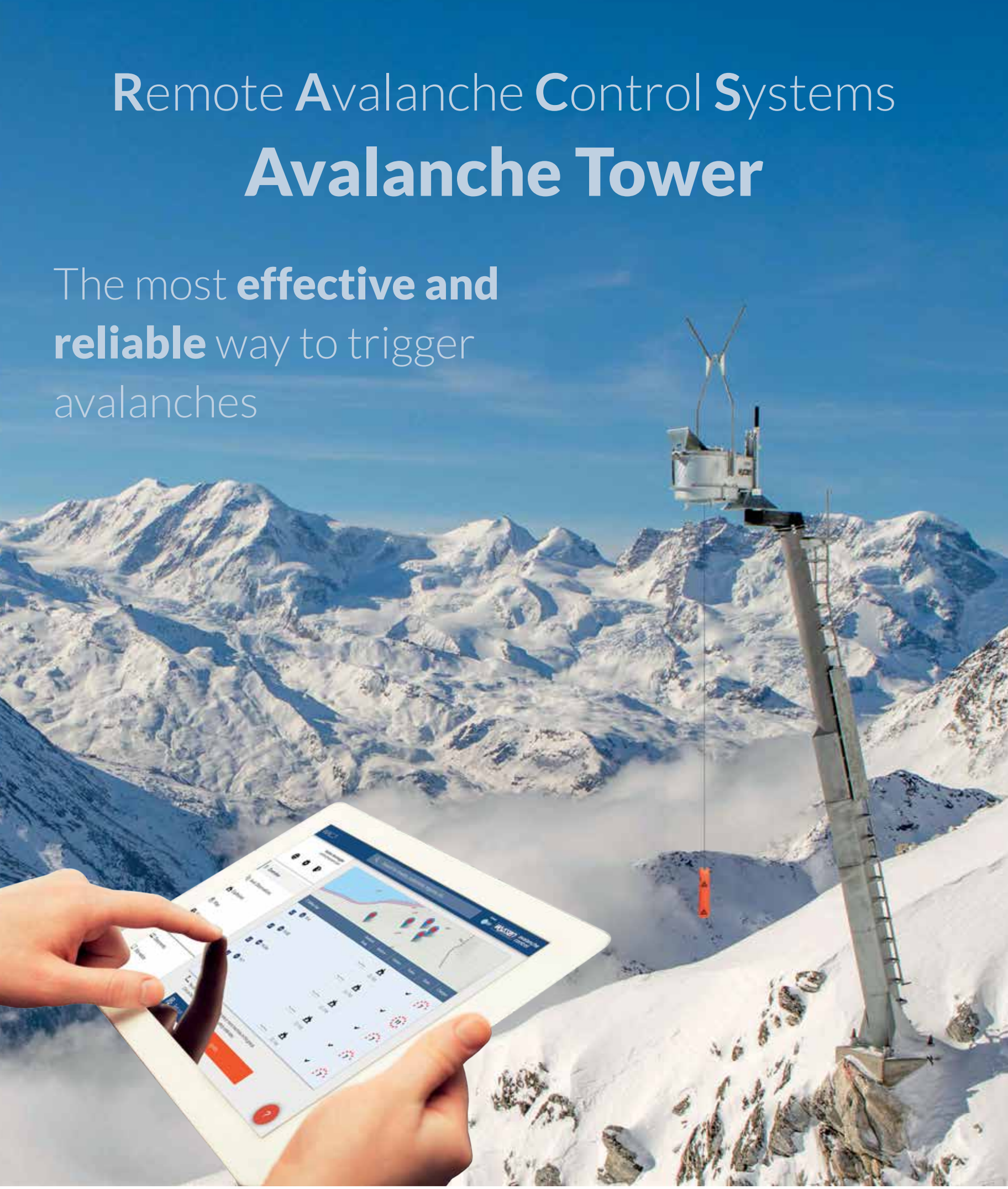


Figure 1: Overview of avalanche detection systems (radar, infrasound and geophones).

Remote **A**valanche **C**ontrol **S**ystems

Avalanche Tower

The most **effective and reliable** way to trigger avalanches



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avalanche control

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Currently nine systems are operationally used in Switzerland, Norway, Canada and USA (Figure 2). In Canada, an infrasound avalanche detection system has been operated in Glacier National Park for two winter seasons. Last winter the system detected 136 natural avalanches, 137 artillery explosions and 59 controlled avalanches. The detection system notified the forecasters of the onset of natural avalanche cycles and whether artificial avalanche control was successful. This information allowed the forecasters to plan and execute control sessions even more efficiently and thereby reduce closure times of the Trans-Canada-Highway.

In Switzerland, Canada and Norway extensive verification campaigns have been conducted over the last years (Steinkogler et al., 2016). The infrasound system was used to monitor certain avalanche paths which endanger local roads and to define the smallest avalanche size which can be detected. Although the system detected many of the smaller slides (size 1-2), they were not automatically visualized and identified as avalanches as they were below the defined thresholds. Mid-sized and large dry slab avalanches were correctly detected. Additionally, large dry avalanches could be detected up to 14 km away from the system.

Infrasound systems have been deployed in a variety of climatic conditions, ranging from a maritime climate in Norway to lower elevations and high inner-alpine regions in Switzerland and Canada. At one of the locations, more than two meters of dense (250-300 kg/m3) snow with several ice layers covered the sensors which influenced the quality of the signals. Yet, a generally thick snow cover without ice layers has shown to filter out unwanted frequencies (e.g. traffic noise) and enhance the reliability of the system. Strong ambient noise, such as wind, has shown to complicate the identification of the avalanche signal.

The infrasound system proved to be a very valuable tool for gathering information about avalanche activity of multiple avalanche paths in a larger area. Since it is continuously monitoring it also provides data on spontaneous avalanche activity, which can be very useful information for the local avalanche control team (*Figure 2, green arrows*).

GEOPHONES

Technical description

Geophones detect the ground vibrations induced by an avalanche in rather close distance to the sensor. So far, the installation of geophones was mainly done very close to the flowing path of the avalanche and the release areas. Avalanches can be reliably detected with approximately 50 m distance to the sensor (*Table 2*).

Experience with geophones

Seismic sensors have been applied for operational and research purposes for many years (Perez-Guillen et al., 2016). Figure 3 shows an example where three geophones are deployed in the release area of a high alpine bowl. RACS allow for avalanche control to be performed during day or night and the geophones detect if an avalanche was released.

	LONG-RANGE RADAR SYSTEMS	SHORT-RANGE RADAR SYSTEMS	INFRASOUND SYSTEM	GEOPHONE SYSTEMS
MEASUREMENT PRINCIPLE	Direct detection of motion within antenna coverage		Indirect detection of infrasound created by avalanche	Direct detection of ground vibrations induced by avalanche motion
OPERATIONAL RANGE	Up to 5 km	Approx. 500 m	3 – 5 km	Approx. 50 m
MEASUREMENT ANGLES	Up to 90° horizontal and 15° vertical	Up to 90° horizontal and 20° vertical	360°	360
MAX. DETECTION RANGE1	5 km		14 km	Approx. 100 m
SMALLEST AVALANCHE SIZE DETECTABLE IN OPERATIONAL RANGE	Small avalanches (~100m³)		> Mid-sized dry avalanche	Small avalanches (~100m³) if flowing over geophone
DETECTION OF WET AVALANCHES	Yes		Yes (if moving fast enough)	Yes

Table 2: Summary and technical characteristics of radar, infrasound and seismic systems.

Figure 2: Example of infrasound detections in Glacier National Park, Canada. The system detects natural avalanches (green), controlled avalanches (red) and detonations of remote avalanche control systems (RACS) or artillery (yellow).

Figure 3: Integration of remote avalanche control systems (here "Sprengmast") and geophone and radar (blue areas) detection systems in one user friendly web-platform.

CONCLUSIONS

From an operational point of view all systems have proven to have reached a technological level at which they work reliable both, in terms of system stability and avalanche detection performance, and can significantly assist local avalanche control teams (*Table 2*). All three systems need a calibration period (a few avalanches of typical size for the avalanche path) to optimize the parameters and to be fine-tuned to the local conditions and thus minimize false alarms. Generally, an intensive and well-prepared planning phase is essential to achieve the desired functionality and accuracy of the systems.

For authorities operating several avalanche release and detection systems, simplicity is one of the key demands. The integration of all relevant information from RACS and detection systems in one practitioner-friendly and easy to operate platform is crucial. A visualization of the results in a clear and simple way makes it possible to get a good overview at a glance using a mobile phone or laptop (*Figure 3*).

Experiences with the short-range radar system and infrasound system installed in Glacier National Park, Canada, were recently presented at the CAA spring conference in Penticton by Jim Phillips (Parks Canada) and the author of this article. The presentation can shortly be viewed in the member section of the CAA website.

LIMITATIONS

The described characteristics and experiences were gathered with technology applied by Wyssen Avalanche Control and are not necessarily valid in general for other radar, infrasound or seismic technologies or products. ▲

We are excited to inform you that we just won a contract with Parks Canada to build an Avalanche Detection Network in Glacier National Park consisting of 13 infrasound avalanche detection systems and four long-range avalanche radars along the Trans-Canada Highway corridor. This network will be unique in its size worldwide. We are proud to be part of this cutting-edge project in North America.

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AN EDUCATOR'S MUSINGS ON THE PRO/REC SPLIT

STORY AND PHOTOS BY PETER EARLE

The American Avalanche Association (A3) finalized the new educational guidelines in 2017 and the PRO/REC split was rolled out by avalanche educators last winter. With the 2017-18 season in the books, we can look back and glean some insights into the program to benefit educators, prospective students, or anyone wanting to know what's going on in the avalanche education world.

This commentary comes strictly from an educator perspective; I was not involved in the planning or implementation of the curriculum. As a lead instructor for the American Avalanche Institute, I had the opportunity to teach all the new professional and recreational offerings last winter, except Professional Level II (Pro II). Through teaching this variety of classes, I garnered feedback from students, co-workers and industry professionals that I thought should be shared with the greater avalanche community. What follows are hindsight observations from a low-tide winter of teaching a heavy course load in Utah and Colorado.

LEVEL I & AVALANCHE RESCUE FUNDAMENTALS

Whether you are a professional or recreationist in the snow world, everyone begins with the same two introductory course offerings, Level I and the Avalanche Rescue Fundamentals. The Level I curriculum is largely unchanged and offers an introduction to backcountry decision-making and snow science. The Rescue Fundamentals Course is a new one-day course and a great way to dust the cobwebs from student's transceiver skills and get them thinking about what to do in an avalanche. The course also introduces and reinforces components of group rescue considerations that aren't covered during Level I Courses. This class should be taken with your usual ski partner(s), as practicing your rescue skills with the people who will be digging you out in a real incident is invaluable.

After completing these fundamental courses, students decide if they want to pursue the professional or recreational course track. For recreational backcountry users the next course is Level II.

LEVEL II

The new Level II course is great for teachers and students alike; it has de-emphasized the nitty gritty snow science topics (the pros can have that) and focuses on decision-making, terrain management and group travel. I found students to be super motivated and able to travel efficiently, allowing us to work through many different terrain features in the field and discuss strategies for managing simple, intermediate, and complex terrain. Additionally, there's time to practice advanced rescue strategies such as micro-strip search and expanding circle technique as well as taking leadership roles in small group rescues. I had several "aha" moments last year when Level II students were able to find a second victim using one of the techniques listed above, and I'm confident that discovery learning moment will stick with them for years to come.

Level II is the end of the road for recreational users (however refresher courses and re-taking Avalanche Rescue Fundamentals is highly recommended). For the Professional Track we've only just begun.

PROFESSIONAL LEVEL I

The Professional Level I Course (Pro I) is the new baseline for all avalanche professionals. With its emphasis on SWAG snow and weather observations and full profiles, this course is creating observational foot soldiers. I wish there were a way to spend less time in snowpits, but it is important that students leave the course with a consistent pit routine and solid craftsmanship. I found many entry-level students had done very little pit work before this course, and it took the full five days of the course and lots of coaching to reach a passing standard. There is also an emphasis on communicating pit results succinctly and thoroughly using simulated radio calls. No one likes a radio rambler! It may take years to become dialed at interpreting the information gathered from the various observations taught; however, students who pass the course generally leave with reliable and replicable skills which they can take to any professional setting. Whether aspiring to a position at a guiding service, ski patrol, or highway program, or looking to refresh skills after a gap in education (anything over five years), this is the course for you.

RESCUE TEST MICRO-RANT

After administering over 100 Rescue Tests this year, the common theme was that transceiver skills are good, but there's still room for improvement in probing and digging technique. Students struggled to maintain adequate spacing while probing and often probed 10-12 times in an area that could have been covered in 4-5 well spaced probes. Additionally, when digging in hard snow (read: "debris-like conditions") students often struggled to dig efficiently. Be strategic! Finally, there should more urgency in all stages of the rescue. If you aren't operating at an anaerobic level by the time you extricate the second target, you aren't working hard enough! There is absolutely no reason that students shouldn't be able to crush the rescue test with flying colors; practice often!

PROFESSIONAL LEVEL I BRIDGE COURSE

This course should be called the Pro I Challenge Test, as you're effectively challenging the standard and testing out over a two-day period. Most students showed up prepared for this course, however this course rendered more failures than any other course I taught. Generally the students who struggled were very new to working in the professional setting or simply didn't practice prior to the course. AAI offers a robust video library as well as other pre-course materials that students reported helped them immensely in their course preparations, and likely made my job as an evaluator easier. Bridge courses will be offered for two more seasons; however, if it has been more than five years since your Level II, I highly recommend taking a full Pro I Course, as you will retain much more from it.

PROFESSIONAL LEVEL II

I didn't have the opportunity to instruct a Pro II last year, but I reached out to several students and instructors and will attempt to synthesize their feedback. First off, students reported the Pro II to have a greater workload than the old Level III. There is greater emphasis on forecasting, and exercises that require synthesis between on-the-fly pit results, likelihood and size of avalanches, and return period for specific terrain using topographical maps. One bonus is that there are no formal snow profile evaluations or rescue tests as

A team of students works together to complete a full profile on a bluebird day in Little Cottonwood Canyon.

Pro I students dig into a fresh crown from a controlled release on the Imperial slide path at Breckenridge Ski Resort. This HS-AE-R3-D3-O/G was triggered by a three pound emulsion hand charge and failed on depth hoar.

A group of students in a Pro I Course work through a field terrain exercise along the ridge at Breckenridge Ski Resort.

these are assessed in Pro I. The end result is a focus on forecasting and a big picture mindset. If you're considering a Pro II course, remember this course is designed for those who have a number of years under their belt in a professional setting. It may not be appropriate for newer patrollers or entry level guides to take this course as soon as they may think. Consider your work experience as a precursor to this course and dive in head first only once you're ready.

FINAL THOUGHTS

To summarize my experience last winter, the new educational standards are delivering a far superior learning environment for recreational and professional students alike. Separating the two user groups allows for more focused and applicable presentations and discussions.

With such a heavy emphasis on hard skills in the pro courses, I think we should not forget about the importance of professional decision-making, communication, and ultimately worker safety. It is challenging to "teach" decision-making, it generally comes from repetition and pattern recognition, but it is a cornerstone of worker safety. I am concerned that a heavy emphasis on SWAG standardized observations and snowpit technique may gloss over the need for the soft skills that often keep us alive in avalanche terrain. I work hard to find time in content-heavy courses to emphasize communication using Crew Resource Management and to discuss tools to make decisions in an operational setting.

One of the most interesting observations came from the courses that included patrollers, guides, and other burgeoning professionals. Hazard recognition should be the same regardless of discipline (ie the patroller targets the instability while the guide may avoid it). With mixed student groups, patrollers told stories of ski cut near misses, unexpectedly large cornice failures, as well as other notable results. Guides often maintain a margin with guests that keeps them away from these most active results and it was great for them to hear recounts of these close calls. Conversely, patrollers learned from their guiding counterparts the complexity and nuance of moving through terrain as well as partner management. A number of recent close calls and accidents in the mitigation community have involved improper safe zones or poor communication with route partners. The cross training that occurs between disciplines in the Pro Courses will ultimately increase the safety and knowledge of both groups.

There are still challenges ahead as we move to year two of the New Educational Normal (NEN for you telemarkers). I think our current trajectory is leading us in a great direction for more knowledgeable and safe recreational travelers and avalanche professionals. We are using uniform nomenclature, performing the same stability tests, and making consistent and replicable observations which all aid our information sharing. This will make us all better members of the greater avalanche community.

For anyone taking a professional course this Winter, I offer the following tips for success:

TIPS FOR STUDENTS IN PROFESSIONAL COURSES

- Come prepared! You will be swamped if you don't practice what you know before starting class. Begin preparing at least a month early.
- Show up well rested and block out your schedule during the course. Don't work a second job or participate in late-night social activities. There is an abundance of homework that will tie up your evenings.
- Whether you take this course in your home range or travel to a new zone (there are good arguments for both) be sure to have a quiet and comfortable sleeping arrangement. Nightly internet access is essential as well.
- Get out in the snow, dig pits (full, test+, and test) and make SWAG standard snow and weather observations with mentors.
- Develop your professional skills. There are mapping and terrain evaluation exercises (in Pro I) that pair with operational planning exercises (in Pro II) that will challenge you. Practice using topographical maps.
- Review snow crystal ID—The International Classification for Seasonal Snow on the Ground has great photos for review. http://www.cryosphericsciences.org/snowClassification.html
- Read pertinent books/articles (Staying Alive in Avalanche Terrain or Snow Sense for Pro I, current mechanics research and metamorphism processes for Pro II).
- Bring a positive attitude and willingness to learn and share knowledge with your peers.

For more information on course offerings and providers visit: www.americanavalancheassociation.org/educators/ ▲

Peter Earle is a lead instructor for the American Avalanche Institute and a forecaster and guide at the Park City Powdercats. He began his career in 2004 as a ski patroller and forecaster at Canyons Resort in Park City where he learned the joys of placing explosives and skiing powder. He lives in Park City with his young wife and old dog.

AVALANCHE SCIENCE AND SAFETY PRACTICES IN A HIGH SCHOOL CLASSROOM

BY MICHAEL TOWN

I'm writing to share some avalanche-related work we've been doing in our high school science and engineering classroom at the Lakeside School in Seattle, Washington. Inspired by previous work in secondary settings (e.g. Hinckley and Englert 2008, Carpenter and Deighton 2016), I have incorporated avalanche science and safety practices as a mechanism for teaching science and engineering practices. Below I share context, unit progression, rationale, some lessons learned, and solicit feedback for future steps.

I chose avalanches as one focus for the course because they present a regionally-relevant combination of fascinating physics, geophysics, and decision-making problems. Constrained by other curriculum, previous work in secondary settings necessarily stays at the Awareness or Level 1 stage. I have attempted to let loose the reins on time management, finding access points to important physics and engineering learning goals in avalanche studies like motion, forces, shear, stress, evidence-based decision-making, design process, and collaboration.

The avalanche science and safety practices unit presented here is a four-month-long unit in an upper-level elective called Advanced Physics: Applications and Engineering. The context is a medium-sized (~550 students) independent high school in Seattle, WA, with a classroom population of eighteen students. The primary goal of the course is to teach the scientific method and engineering design process at a deep level by engaging in real word problems. The curriculum has many content and pedagogical influences (e.g. BIE, 2015; Hill, 2013; Wells and Hestenes, 1995; Johnson et al., 2015), and now includes parts of avalanche Level 1 and Level 2 curricula.

More specifically, I cover basic snow and avalanche physics, trip planning, field work, numerical computational modeling, instrument calibration, and the engineering design process. The challenging nature of modeling complex processes, making accurate measurements in the snow, and outdoor travel naturally forces collaborative decision-making.

Nitty gritty—so what do we actually do?

The unit goes from mid-December through early May. We begin with some background research and theoretical work that gives students context and vocabulary surrounding avalanches. As snow begins to fall in the Cascades, we transition to preparing for and executing two days in the field. We then calibrate our field instrumentation and try to tell a data-based story of the snow. The unit ends with students working in small groups on an avalanche-related question or problem of their choice (*See Table 1*).

Background research

We begin in mid-December with some intensive background research to develop an operational avalanche vocabulary and understand current issues in avalanche safety. Students are exposed to stories like Snow Fall: The Avalanche at Tunnel Creek (Branch, 2012) and Rescue at Cherry Bowl (Avalanche Canada, 2016). We read the avalanche forecasts produced by the Northwest Avalanche Center (NWAC). A local avalanche professional associated with NWAC often comes in to give an avalanche awareness talk. AIARE Avalanche Instructor Lyra Pierotti has done this for us in the recent past. This year, she led students through a lesson in which students sketch visualizations of snowpacks at different elevations based on a month of daily weather data. The lesson became a touchstone of conversation for the year. I repeated the exercise two more times, raising content expectations each time.

Numerical computational modeling

After students have some background on avalanches and their surrounding problems, we apply a physics lens to a local site. I ask students to make a data-based simulation of the speed profile and runout distance of a slab avalanche at a local mountain pass (Pineapple Pass, WA - just north of the Alpental Ski Resort near Snoqualmie Pass, WA). This has the multi-pronged effect of forcing students to: 1) apply their understanding of inclined-plane, friction, and momentum to a real-life problem, 2) become proficient at numerical modeling on a 21st-century platform (Excel or Python), and 3) develop computational troubleshooting skills (e.g. how do you know when you are right?). Spirited students are invited to include other factors like air drag, rolling/sliding physics, or also use another physics lens like conservation of energy to solve the problem. These models of simple and intermediate complexity put in perspective just how fast and far avalanches can run.

Field work—preparation and execution

The next step for us is to prepare and execute two field trips to the Cascades. We encounter an exciting positive feedback between learning about backcountry travel, data collection, and snow science. Understanding the snow will help you be a better traveler and field tech, while understanding how to travel well gives snow scientists a visceral understanding of their theoretical topic and a practical understanding of how to measure. So, we spiral around these three topics.

Constrained by how much time we can spend in the field, I've been challenged to see how much we can learn in the classroom. It turns out, with some proper context and scaffolding, students can learn quite a bit prior to being in the field. Snow characterization processes (CT, ECT, PST, hand hardness, snow temperature, snow density, snow grain/habit identification, shear strength) are learned by triangulating tutorial videos with the SWAG. This tack opens up some peer-to-peer learning options and saves us all from a lot of cold, eye-glazed, foot-stomping in the field while listening to 'experts' (i.e. myself) drone on.

Our fieldwork has occurred at one of two snoparks just east of Snoqualmie Pass, WA. These sites are optimal for their safe access to snow and,

Unit Stage	Timing	Details
Background Research	mid-December through early January	Read NWAC forecasts, case studies, Staying Alive in Avalanche Terrain. Interact with avalanche professionals.
Numerical computational modeling	Early January through mid-January	Data-based simulation of slab avalanche speed profile and runout distance for Pineapple Pass, WA. Platforms used are Excel or Python.
Field work prep	mid-January through late January	Study avalanche-related snow profile and other snow science tests. Learn trip planning basics.
Field work	Two day-trips (late January and mid-February)	Travel by snowshoe in a Washington State Snopark. Perform ava snow profile and other snow science tests. Collect data autonomously on snow temperature with iButtons.
Data digitization and instrument calibration	Late January through late-February	Digitize and reduce data. Archive data in course archive database. Calibrate field instrumentation and apply calibrations to data.
Snowpack Story	Late February through early March	Use regional and in situ data to explain the observed structure and evolution of snow.
Independent student projects	Early March through early May	Work in small groups on avalanche-related question or problem. Interact with professionals (e.g. avalanche professional, patent lawyer). Present work in public poster session.

Table 1. Student activities and timeline for a high school avalanche science and safety practices unit.

Figure 1. The Silver Turkey. Not just a salt shaker, but a pedagogical tool supporting peer-to-peer learning and group decision-making.

importantly, heated bathrooms; some students have not spent the day in the snow before, let alone used a blue bag. The downside is that we are below treeline (BTL), and so only see BTL snowpacks. Constrained by the school day, traffic, and distance from school to snopark, our ideal timing only puts us in the snow for about five hours each day. Our partnership with the school's outdoor program means that all students have the necessary gear to remain warm. Presuming no snow skill, we all travel by snowshoe.

Once on site, students break into groups of three or four to dig snow pits. It takes almost an hour the first time. After lunch and a story or two from our sage outdoor program director, we begin measurements. There are enough student groups that we break the measurement duties amongst the pit teams, and students collect data for another hour.

Students have each filled out an AIARE Backcountry Decision-Making Guide for the trip. Similar to an AIARE Level 1 course, students establish a visceral connection with the snow while working in the snow. Students check their predictions about snowpack structure and reactive layers, making this a powerful calibration experience. Ideally we return once more to the field. The second trip is logistically much smoother, leaving space for more skill development and data collection. The second field experience also allows students to personally witness the evolution of the snowpack due to local and regional meteorology.

Data digitization and instrument calibration

Back in the Crime Lab, we have a few goals. The first is to digitize and plot the class-wide data. We then examining the preliminary data and connect it to our physical experience. Students often refine their data collection process based on this reflective discussion. We then calibrate the field instrumentation, a necessary skill for any field tech. Students review and reference calibration reports from prior years, improving on prior student efforts while producing a calibration history of each piece of equipment.

Inferences from data: A Snowpack Story

This past season (2017-2018), our second field trip was skunked by some intense weather. However, some small autonomous temperature sensors measuring a temperature profile required retrieving. The snow was mostly isothermal during this time, but the data provided fodder for a lesson on making inferences from data. These were temperature data, but they told a story of snow densification as the temperature sensors were gradually exposed to the atmosphere during the intervening two weeks.

Following this discussion, students were asked to tell their own 'snowpack story' connecting regional and the class-wide in situ data to each other, explaining the structure of the snowpack we observed. We do this by spiraling back again to our field data, but this time the data are cleaned and calibrated. This dovetailed with Lyra Pierotti's initial 'build a snowpack' lesson; we were also fortunate to have relevant exemplars from the April 2018 issue of TAR.

Title	Brief project description
Trends and patterns in fatality data from 2011-2017	Students read six seasons of accident reports and codified everything they could (mode of travel, burial, cause of death, size of avalanche, etc…) looking for trends.
Stability of NWAC forecasts from day 2 to day 1	Students used a year of data provided by NWAC to assess the stability of NWAC's avalanche forecast at Snoqualmie Pass, Washington.
The 'Buddy Airbag System'	Student developed an idea to have all airbags in a party wirelessly paired such that if one person activated their airbag, all airbags in the party would activate. They demonstrated the feasibility of this idea by getting two Arduino switches to wirelessly trigger each other.
Vector victim location by networked avalanche transceivers	Student idea to triangulate the location of a victim by finding the intersection of concentric spheres around searching parties. Once a signal is acquired, a single searcher (or party) would quickly deploy two more stationary transceivers spaced out across the avalanche field, and the networked transceivers would compute a direct vector from the 'primary' searcher. They demonstrated the feasibility of this idea by writing software to do this computation in Python.
A backcountry trip-planning and decision-making app	An avalanche decision-making app that computes a trip vulnerability score based on group size, party member experience/skill, trip plan, and the current avalanche danger. They wireframed their app in Balsamiq, and calibrated their score calculator on scenarios of their own design, and known scenarios like The Avalanche at Tunnel Creek and Rescue at Cherry Bowl.

Table 2. Examples of independent student projects in an avalanche science and safety practices unit in a high school classroom.

Student Reading Layers: Avalanche science student collecting data Hyak Snopark, Snoqualmie Pass, WA.
Photo Mike Lengel, Lakeside School

Independent student projects

The final stage of this unit is a small group, open-ended science or engineering challenge. Students will have inevitably observed an unanswered question, a looming problem, or a cumbersome process. Students have impressed me with their deep, creative thinking and authentic, successful engagement in the scientific or engineering design process. As the projects build on themselves from year-to-year, we also get some compelling and relevant projects (e.g. checking the stability of NWAC's forecast, developing wirelessly networked airbags, finding recent trends in U.S. avalanche fatalities; see Table 2 for more details).

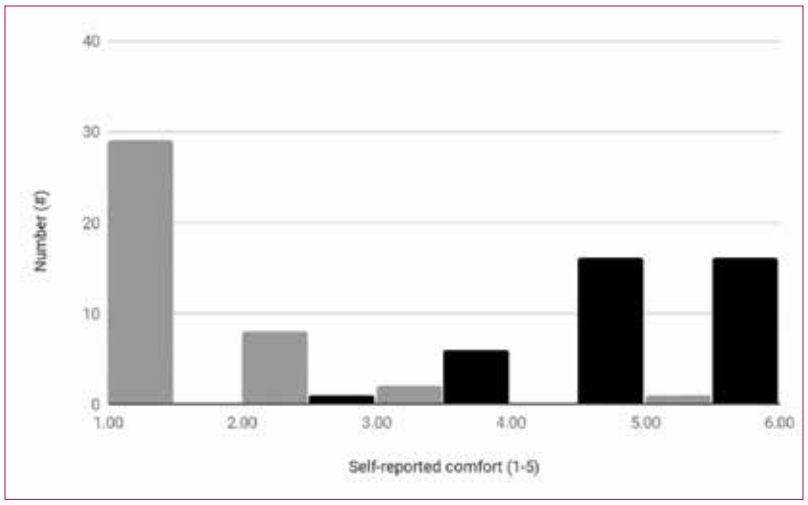

Figure 2. High school student self-reported comfort with preparing a snow pit for analysis before (gray, n = 39) and after (black, n = 38) an avalanche science and safety practices unit. Data collected over two school years (2016-2018).

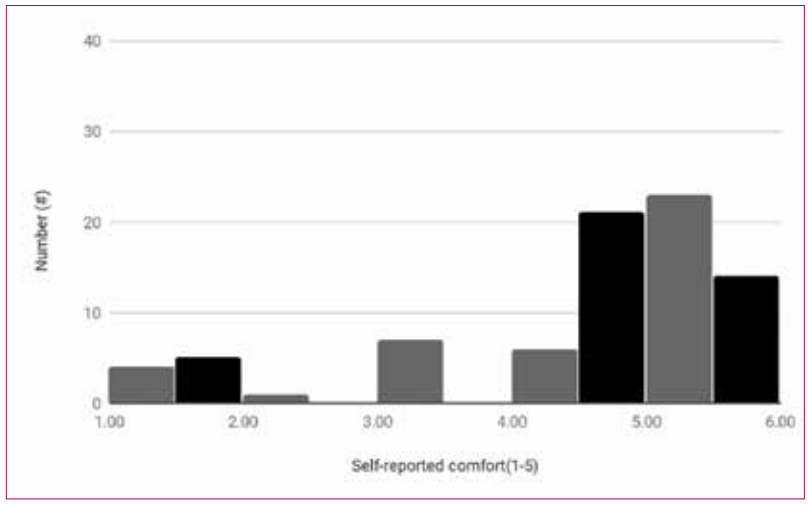

Figure 3. High school student self-reported comfort with being outdoors in the snow all day before (gray, n = 39) and after (black, n = 38) an avalanche science and safety practices unit. Data collected over two school years (2016-2018).

How are we doing? Strikes and gutters.

How are we doing? Well, it's a little like my bowling game: strikes and gutters.

Deep learning requires time. The time goes a lot of places: background research, discussions, rabbit holes, black holes. A big time sink is also iteration. We iterate through modeling and design processes to create high quality products, but also to train troubleshooting skills and build academic resilience.

To some degree, I have allowed avalanche studies to crowd out other potential academic content. The looming questions are: Is it 'worth it' to spend so much time on one thing? Are generalizable skills and content being learned? I believe 'yes,' but I'm still trying to justify this. A pleasant surprise has been seeing 'sacrificed' content like electromagnetism and stewardship reemerge as students dive deep into avalanche studies.

People do not like to feel stupid. Shocking, but true. This makes admitting to mistakes and misunderstandings difficult, resulting in unfortunate (and potentially dangerous) outcomes when we are interdependent. It is also somehow easier for students to admit to corporeal mistakes (e.g. in the shop) than cognitive mistakes (e.g. in the classroom). To normalize confessions and peer-to-peer learning, a colleague and I celebrate mistakes with a pedagogical device called the "Silver Turkey" (*Figure 1*). With permission, we nominate each other to tell a story about a recent mistake that we can learn from. Part penance, part reward, the storyteller then keeps possession of the Silver Turkey until the next Silver-Turkey-Worthy Event. The Silver Turkey has helped mitigate, but not eliminate, taboos around sharing and learning from mistakes.

This work has also uncovered some uncomfortable realizations about my personal culture surrounding right and wrong, and their intersection with style. The tension between being 'right' and maintaining positive relationships looms in all charged, interdependent endeavors. Has anyone else ever gotten upset with or belittled someone who has made a mistake? Or felt the social brunt of their own failures? What do you do to make these circumstances easier navigate, and so easier to learn from?

Measuring growth is difficult. I try to teach like a scientist, and so I'm constantly collecting and learning from classroom feedback. I'm currently concerned with how to evaluate subjective things like process skills, communication, or group work. Table 3 shows my recent attempts at understanding how well students are learning field work processes. Figure 2 shows the histograms for one category, the self-reported 'comfort with analyzing a snow profile,' evaluated on a 1-5 scale. These histograms are typical of almost all self-reported pre- and post-unit data collected. The exception is self-reported 'comfort with being outside in the snow all day' (*Figure 3*). Figure 3 indicates that many students are more comfortable being in the snow all day, despite the post-unit average being lower than the pre-unit average. It turns out that several students who reported a comfort level of 5 admitted to less comfort after our work outdoors. My inference here is that snowy mountains can be a healthy treatment for the common human pathology 'overconfiditis.'

These data in Table 3, Figure 2, and Figure 3 are pretty squishy. Any inferences about effectiveness of instruction must be taken with a large grain of salt. However, the data are encouraging. Combined with written feedback from the students, I have some tangible information act on. On the other hand, I'm still pretty far from effectively measuring growth in communication or working in groups. Suggestions are welcome.

Understanding and empowerment can fuel environmental stewardship. A rationale that is probably similar to one held by other outdoor educators: if the natural world is not menacing and presenting unmanageable hazards, then it becomes less a place to be feared and tamed but a place to be respected and preserved. I have no direct way of understanding how I'm doing with this affective goal, but I'm open to suggestions and conversations. I know that there are many professionals in the avalanche community who have thought deeply about this subject.

It takes a village. This work could not have happened without folks from many sectors of our school and professional community. As a testament to the inherently broad scope of avalanche and snow science, I have received help from teachers, administrators, outdoor educators, guides, engineers, avalanche forecasters, non-profit executives, and snow science researchers. Their knowledge and generous spirits have helped push this work to something I was willing to share. Specific acknowledgments are below.

Where to go from here?

There always seems to be more to do, but some things my colleagues and I are currently looking towards are: 1) fostering and measuring positive, effective, and efficient communication in groups, 2) better scaffolding of complex processes and skills prior to fieldwork, 3) developing a student science/engineering community that learns from previous generations.

In taking my classroom model to heart, I am in an iterative stage of sharing my work and gathering feedback. As such, I am open to questions, comments, criticisms, and suggestions for improvement. I also hope something we've done is relevant to your work, informative, or inspiring.

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Prompt: Rate your...	Pre-unit (mean +/- 1 sd)	Post-unit (mean +/- 1 sd)
… *comfort with* being outside in the snow all day.	4.12+/-1.26	4.05+/-1.16
… *comfort with* reading a map of the backcountry.	2.61+/-1.37	3.50+/-0.89
… *comfort with* preparing a snow pit for analysis.	1.41+/-0.82	4.21+/-0.81
… *comfort with* analyzing a snow profile	1.33+/-0.81	3.89+/-0.83
… *comfort with* your ability to calibrate instrumentation before or after field work.	1.71+/-0.97	3.79+/-0.70
… *current understanding of* how to assess avalanche conditions.	2.10+/-0.88	4.23+/-0.59

Table 3. Self-reported student comfort data from the avalanche science and safety practices unit from 2016-2018. Students were given several prompts on which to rate themselves with a 1-5 scale before and after the unit. N = 39 for pre-unit data. N = 38 for post-unit data. Read the standard deviations as imperfect characterizations of the population distributions, rather than an uncertainty in the mean.

Avalanche science students collecting data Hyak Snopark, Snoqualmie Pass, WA.
Photo Greta Block, Lakeside School

Avalanche science students at Hyak Snopark, Snoqualmie Pass, WA.
Photo Greta Block, Lakeside School

Highland Bowl

34 years ago, a monumental avalanche wrote a tragic chapter in Aspen history

BY TIM COONEY, ASPEN JOURNALISM

Aspen Journalism is an independent nonprofit news organization. See www.aspenjournalism.org for more.

Editor's Note:

I received a link to this story from Rod Newcomb, saying that it was "a fantastic story with a message." When I was able to procure the text and photos for this TAR, he added, "Splendid. I knew Snyder, Kessler, and Soddy from the early pro courses in Jackson. I recall that they liked to party at night. The avalanche in Highland Bowl cut to the core of every snow safety patroller working at the time."

What many Highland Bowl lap counters and sixth-gear cruisers now take for granted as an everyday occurrence is only possible because of the sacrifices made by a distinguished lineage of Bowl-focused snow experts on the Aspen Highlands Ski Patrol going back to the 1970s. To this day, they put their skin in the game to tame what was once thought to be an unmanageable ski wilderness.

One event stands out in Bowl history: an avalanche on March 31, 1984, that took the lives of three ski patrolmen. The day began in Aspen with temperatures in the mid-30s, as fanciful clouds scudded across a deep blue Colorado sky, with no hint of imminent tragedy.

At 11 a.m., "4-7 Control Team" consisting of Tom Snyder, Craig Soddy, and Chris Kessler left Loge patrol room to hike the bowl and do snow safety work. After launching a number of two-pound charges off the Highland Bowl ridge leading to Highland Peak, they skied down between the resultant craters in upper G-8, before stopping at the North Woods edge one-third of the way down, one eyewitness said. Eyeing their objective in the lower-middle section of the Bowl, they consulted.

Their confidence was based on historic Highlands documents of snowpit analysis, the strategic placement and some deep burying of nearly 200 charges in upper Bowl starting zones throughout the 1983-'84 season, and a remarkably cohesive upper Bowl snowpack that had defied season-long efforts to shake it loose. One by one they traversed to the skiers' right-center bench of G-8, deep in the tangible sacredness that Bowl travelers of all eras know well. There they deployed a launcher dubbed "The Ultimate Weapon," an effective device that sling-shot charges into places too far to otherwise reach. They planned to put three more charges into a refilled lower pocket that had slid on March 8 and twice in December (the first slide in early December was naturally triggered).

The first charge to the skier's left in lower B-1 (now between lower Ozone and Be One) brought no result. Then they launched the second of the charges below them where the pitch steepened. They never got to launch the third. What happened and why has become a look-back topic of armchair quarterbacking. But examination of original Highlands snow safety and ski patrol records from that time and interviews with at least a dozen individuals with knowledge of these matters add much more to the story.

Men of the patrol

For those who don't know and for those who may remember, Snyder, 35, Soddy, 29, and Kessler, 27, were three devoted ski patrolmen in the prime of life. Memory of them deserves a nudge, especially if one passes by the plaque that bears their names near the top of the Loge lift.

Craig Soddy

Tom Snyder

Chris Kessler

Tom Snyder "was up there every day with a magnifying glass," said then-assistant patrol director John "J.R." Rupinski. After studying at avalanche schools in Alta and Jackson Hole, Snyder took to being one of the first Bowl snow-safety leaders. As an early student of the morphing snow layers and hidden shear surfaces in the Bowl, he helped establish a foundation of knowledge that underlies Bowl understanding today.

Snyder lived in his van in the Highlands parking lot, which Whipple Jones, known then as a thrifty ski-area owner, allowed selected workers to do. After nearly nine years patrolling, that season was to be his last. He had been saving money to attend Arizona State University and become

a respiratory therapist. Friends recall him as the ultimate pro at whatever he did, from EMT to avalanche work. At a patrol banquet earlier he received "The Best Patrolman Ever" award. He had a girlfriend, played AA volleyball, drove a sports car, and was known as an "action man."

Craig Soddy, survived by his wife Amy, had some three years patrolling under his belt. Unofficially he acted as the patrol ski trainer, taking patrollers out to ski difficult snow on the narrow, unforgiving skis of the day. As a ranked tennis player and ski racer, he knew how to focus. Fellow patrollers recollect him as serious on the job, "first class," and an "all-around patroller." Another characterized him as "Captain Enthusiasm." He capped those qualities with his quick wit and sense of humor that put those around him at ease.

Chris "Crash" Kessler was the popular Aspen-raised kid on patrol. Ready to ski anywhere, any time, he kept his stuff in a pile called "the black hole" in the locker room. If anything was ever misplaced, patrollers quipped, "did you check the black hole?" He owned a horse, rode some rodeo, and taught country swing dancing at Aspen's onetime Chisolm's Saloon. Several years before, he had been buried and rescued from a slide onto Highlands' P-Chutes Road. At the time of his death he was engaged to be married.

Notably, Kessler raised "Chopper," Aspen's first official avalanche rescue dog, who sired many pups in the valley. After Chris' death, Chopper served at both Snowmass and Aspen Mountain. Chopper's daughter, Bingo, followed him next on Aspen Mountain.

First descents

Perhaps Everest climber George Mallory's saying, "because it's there," explains why so many have challenged the imposing ski terrain of the Bowl. But who skied it first?

Among the known early Bowl skiers, the adventurous Marolt family of Aspen have a picture of their great-uncle George Tekouzic standing in ski gear at the bottom of the Bowl, below Ozone, taken in 1941 before he went to World War II. The presumption is that he skied it.

The late Pete Luhn, one-time head of the Aspen Mountain packing crew, high-limb tree trimmer and letter-writing wag, claimed to be the first to ski the bowl from the top, in the early '60s, "straight down from the peak, with a hangover," he said. Some other high-mileage Aspen skiers say that Earl Shennum, who built the Ullr apartments on Main Street, could have blitzed the main Bowl first in 1963 or 1964.

On Feb. 15, 1968, Highlands ski patrollers Jim Flanagan and Matt Wells survived a large slide in today's G-6 area, according to the periodical Colorado Geological Survey publication *Snowy Torrents*. Flanagan and Wells went to "check bowl conditions." They threw "two 7-stick, 40 percent nitro" [dynamite sticks] from the top, one from the peak then one in their intended ski line, with no results.

First to ski, Flanagan became submerged in an 800-foot slide that cracked below Wells, who rescued Flanagan. Flanagan recounted that a form-fit snowball had packed his mouth so tightly that he was unable to breathe, yet he managed to chip it away with front-teeth bites until he could pull it out with his fingers. Both went on to serve long careers together on the Sun Valley ski patrol.

In the 1970s, way before regular control work of the terrain, numerous ski banditos poached the odds. Infamous brothers Theo and Ted Meiners, along with Dave "More Mud" Nelson, often took the handicap bet in the late '70s. Theo went on to run Alaska Rendezvous Guides in Alaska, contributing much to modern snow science, before his death in 2012.

Post-1979, when Colorado passed the Skiers' Safety Act, skiing in closed terrain within ski-permit areas put violators at risk of arrests and fines. This upped the bandito ante, precipitating a brief era when Highlands patrol chased stealth poachers. Ski-bum greats Rick Wilder and Denis Murray regularly ripped there in those days.

In 1982, Aspen mountaineer Lou Dawson joined what the underground called "The Highlands Bowling League." This required a run down the gut from Highland Peak for membership. Some 100 feet in, bad luck and snow science intersected and a colossal avalanche took Dawson 1,200 feet to the flats, while his partner John "Izo" Isaacs watched. Spit out near the surface, Dawson endured two broken femurs and hypothermia before Izo found him and ski patrol evacuated him. Dawson's written account of the event highlighted "a private moment" during the tumble, which lowered his risk-taking gambles from then on.

Former Aspen Mountain snow-safety director and 1970s Highlands patroller Doug Driskell recollects naming the G, B, and Y Bowl zones along with patroller Doug Childs after the colored waxes used for different temperature aspects: green for cold, blue for moderate, and yellow for warm. With time, the numbered zones acquired more delineations as patrol named specific snow-safety routes and ski lines.

Viable boundaries

Because Highlands owner Whip Jones wanted to keep his permit area boundaries viable, Highlands patrol examined the Bowl more closely in the late '70s. Between 1980 and 1983 they started the Bowl snow-safety department, whose job was to figure out the Bowl so that they could conduct public ski tours.

The first Bowl keepers worked with a tight budget from Whip, as they explored, charted and tried to harness the skiing wilderness. The systematic techniques and tools they developed to manage the terrain grew from their studies of snow under the tutelage of iconic snow rangers such as Ed LaChapelle, Rod Newcomb, Liam Fitzgerald, Pete Lev, Betsy Armstrong, and Knox Williams.

At the risk of rhapsodizing a cliché, ski patrolling in the '70s and '80s had a cowboy aspect to the job. Patrollers at major western ski areas routinely headed out the door in pairs on big snow days to their "avi routes," their zipped coats stuffed full of two-pound charges secured within by a first-aid patrol belt. Tentacles of red fuses bristled out at the necks of their coats,

George Tekouzic after skiing Highland Bowl in 1941 before shipping off to World War II. Tekouzic was the great-uncle of Roger, Steve, and Mike Marolt. Tekouzic was probably one of the first to ski down the Bowl. *Photo Marolt family*

A 1970 independent group of skiers heading up the Bowl ridge to ski the Bowl. *Photo AHS, Rick Lindner collection*

A patrol-led Highland Bowl ski tour circa 1982. Snow Safety leader Kelly Klein stands with gloves in hand front row left. Assorted other Highlands ski school, patrol, and visitors stand behind Klein. *Photo AHS, Andy Hanson collection*

Bowl photo taken that same day from Snowmass patroller Tom Stiles' plane shows the secondary, upper slide that overtook the three patrolmen standing on the bench in G-8, one-third of the way down. *Photo Hal Hartman*

Snyder had built confidence in upper-Bowl stability based upon his season-long observations that extensive explosive testing and snow pits confirmed.

The upper part of the 3/31/84 avalanche taken two days later by Melahn from Loge. *Photo O.J. Melahn*

Charge going off in upper B-1 area before the two shots in G-8, and before three skied down to the bench. Photo was recovered from Kessler's buried camera.

extra ignitors lined their goggle bands over wool ski hats, and a lip bulge of chew sometimes accompanied their mission.

First Bowl keepers

In 1980, the first official Bowl specialists Tom Snyder, Kelly Klein and J.R. Rupinski, along with a number of patrol alternates, set to work evolving a disciplined approach, backed by a methodical set of record keeping, to what was then called "avalanche control." In today's more muddy-water jargon the job is called "avalanche mitigation," lest litigation find monetary wiggle room.

In any case, observation, visitation, terrain history, snow study pits, temperatures, wind transport, storm data, explosives, early ski packing, ski cutting, and snow intuition were the major tools of boundary exploration then. Steeplechase served as a kind of Bowl training ground before Whip okayed moving up the ridge to the Highland Bowl as an expansion opportunity.

Boot-packing in starting zones to bust up less-cohesive early-season faceted snow — known as depth-hoar — with the aim of nursing better bonding with subsequent snow storms remained a relatively new field tool then. The practice hadn't yet become the well-financed wall-to-wall discipline deployed these days.

Multiple explosives in Highland Bowl and some in Olympic and Maroon bowls became part of the patrol's widening awareness of the terrain around them in case of out-of-bounds rescues. The schooling then taught that explosives moved weaker snow out while stronger snow remained, a process called flush and refill.

With the Bowl's beckoning presence, focus narrowed there between 1981 and 1984. Between 1981 and 1983, as understanding of Bowl dynamics increased, snow-safety guides led public tours up on skins before skiing the North Woods side. In the 1983-'84 season, Aspen Highlands ran helicopter tours. Most everyone on the patrol then wanted to go on a Bowl mission, so the early Bowl keepers, who characterized those days as "the greatest job you'll ever love," rotated patrollers through, studied the terrain, worked with the tools they had, and even invented some.

The Ultimate Weapon

Tours in those days rarely ventured deeper into the Bowl than north-facing G-6. The gut still stood as the respected gun barrel where caution ruled. The Bowl team set charges off in the Y-zones and along the ridge into the B-zones and then the G-zones before skiing the conservative north side.

They also set "trunk lines" with simultaneous detonator cord along the giant ridge cornice, at times rappelling into the Bowl to dig snow pits under the lee-side wind catch. Roped in, they deep-buried charges in the starting zones off the ridge, especially in wind slab, sometimes packing in ammonia-nitrate fertilizer for extra kick. Other times they set charges on bamboo tripods to employ air blasts over the pack. All this was part of the discovery process of how to make future Bowl skiing possible, but they couldn't get the charges way down into the center of the Bowl into the deep pockets where they wanted them. For this they invented "The Ultimate Weapon," a sling-shot device made of surgical tubing attached to an elk-skin pouch, which came from the hide of an elk shot by Patrol Director Mac Smith. Bowl leader Kelly Klein recounts, "You had to have a bit of the gunner in you to be the launcher." Two others held the stretched tubing on either side. "You needed to have a low angle," he said, like launching a mortar round, which is why the invention worked so well off the Highland ridge.

In those days, fuses could be cut to a length deemed applicable to the job at hand. Ninety-second fuses worked in the elk-skin pouch, which because of its softness pocketed the charge well. With this new tool they propelled charges much deeper into the Bowl than they could before.

Helicopter access

In the 1983-'84 season, the Bowl keepers upgraded their tools with the addition of helicopter tours. The ship picked people up in the Loge Meadow and whisked them to the top, and then from the Bowl flats up again for three laps. Between tours, snow safety used the ship to drop charges. Vietnam combat pilot "Blue" flew them on those ordinance runs, dubbed "the goat run." The Forest Service didn't want Bowl tours on days the resident big horns or mountain goats were up there. So the Bowl crew devised a pre-run strategy before each tour to check for critters. But of course the chopper spooked wildlife away, and then they did their control work. Blue nailed the chosen spots, tilting the ship in a tight hover so snow safety, strapped in, could ignite and drop charges from the door-less helicopter.

On March 8, 1984, the team dropped a four-pound charge and three six pounders from the chopper into upper G-8, setting off a large slide two-thirds of the way down. Between tours they had been scoping out the Bowl for a possible figure-eight contest for the annual Colorado Pro Ski Patrol convention, scheduled at Aspen Highlands on April 4. Getting that deep spot cleaned out reduced a hazard. If ever there was a year to showcase the Bowl as a canvas for a figure-eight contest, 1983-'84 was the one. Across Colorado the unusually stable equal-temperature (ET) snowpack inspired backcountry skiers and lulled avalanche forecasters into cautious comfort zones; some even ventured superlatives to describe the deep stability. Yet an early cold snap in January threw a wild card into the snowpack.

Surface hoar

Aspen Water Department records between 1934 and 2013 show a record 278 inches of snow for 1983-'84, with 2007-'08 coming in second at 250 inches, and 1994-'95 — a year in which Castle Creek Road closed due to slides — in third place with 239 inches. Typically, the Colorado climate produces intermittent autumn snows resulting in faceted, less-bonding crystals

(depth-hoar) that form because of temperature transference from the warmer ground — which early-season powder skiers experience as "bottoming out." Instead, in 1983-'84, the Colorado winter held off until a few days before Thanksgiving. November delivered a quick 55 inches of snow and December followed with 72 inches. Though some pockets of depth-hoar remained, the near nightly snows of December under cloudy skies kept nighttime temperatures from getting too cold. As the snow stacked past the "magic meter" depth, which helps insulate against temperature transference between the ground and snow surface or vice versa, faceted snow crystals became rounder and bonded throughout the snowpack. This yielded the unusual cohesion that Colorado skiers crowed about that year.

But along came one of Aspen's pesky cold and dry Januarys that can produce surface-hoar, sun-twinkling feather-shaped crystals with lots of air space between, equivalent to winter dew. They form here and there without being a widespread layer, the beautiful bastards of a delicate dance between cold air, humidity, and low winds. Skiers sometimes hear the tinkling sound of surface hoar breaking around their boot tops on a cold first-track morning.

One anonymous ski bandito recalls seeing surface-hoar crystals high-up on Aspen Highlands on Jan. 1, 1984. The month ended with just 10 inches of snow. The 80 inches of snow that followed in February and March buried that layer and possibly other scattered plots of surface-hoar crystals.

According to records shared by the Aspen Highlands Ski patrol, a 10:30 a.m. snowpit dug on Jan. 10, 1984, at the top of South Castle Chute at Highlands, showed a new half-inch surface-hoar layer on top of a firm 60-inch snowpack of "advanced ET" (equal temperature) — by many measures a great snowpack. A 2:30 p.m. snowpit on Jan. 16 in upper G-8 showed traces of old surface-hoar at 33 and 51 inches down from the surface in a solid ET 64-inch pack; the bottom four inches were faceted crystals with bonding.

On March 29, a patrol team led by Snyder in upper G-8 threw charges and dug quick study pits before skiing down to the old March 8 slide path, where they set off a six-pound charge in a deep bore hole, with no signs of instability. Barring snowpack changes to come, this data reaffirmed stability and the possibility of holding the figure-eight contest there a week later.

Tom Snyder heading up the ridge of HB on the day of the avalanche, 3/31/84. Photo was recovered from Kessler's buried camera.

March 31, 1984

The day started with a meeting where Snyder outlined a plan to his snow safety partners Klein and Rupinski. He wanted to retest lower pockets in the refilled section of G-8. Klein had been out for three weeks after knee surgery and was on dispatch handling the radio and phones. Rupinski was running the busy front-side operations — it was a Saturday — while Smith, the patrol director, had the day off.

Snyder had built confidence in upper-Bowl stability based upon his season-long observations that extensive explosive testing and snow pits confirmed. He enlisted Soddy and Kessler as partners that day, two experienced patrollers eager to draw Bowl duties. Of the three snow safety leaders, Snyder took a more offensive approach based upon his observed evidence. Klein counter-balanced Snyder with his more defensive style, but he hadn't seen nor felt Bowl snow for three weeks. Rupinski, too, took a conservative approach to snow safety operations.

Snyder's team would use the launcher off the ridge into the Y-zones, into B-1, and into upper G-8. As documented in *Snowy Torrents*, they would retest the March 8 slide area left of the March 29 tracks with explosives by sending one man in from the North Woods side to toss charges, followed by a hasty traverse back to the trees. Snyder agreed, but footnoted that he wanted to make a field assessment once on scene, depending on upper explosive results.

At the time no cat track existed above Loge, nor were there kicked steps to follow; they broke their own trail. Between 11:30 a.m. and 1 p.m. the team launched five charges from the ridge into the Y-zones, setting off four- to six-inch soft slabs of new snow from the night before. By 2 p.m. they reached Highland Peak and paused while spotters Larry Lembke and Rupinski took a position across the Bowl near Hyde Park after throwing charges to secure the "Monback Traverse" back into Steeplechase from the Bowl, and to establish a safe rescue route. Then Snyder's team launched a charge into upper B-1. No result.

Lembke and Rupinski watched as the 4-7 team's next two charges in upper G-8 above the old March 8 slide path yielded no results. Soddy, Kessler, and then Snyder singly skied down upper G-8 between the explosion craters. Snyder checked the snow profiles in the holes. The three then met at the North Woods edge, consulted, and traversed singularly to the G-8 bench one-third of the way down, Lembke said. Rupinski and Lembke called them and advised caution as the team proceeded with an alternate plan, which put them below the pack that hadn't slid all year. Snyder replied, "Nothing is going to slide today. It's bullet proof."

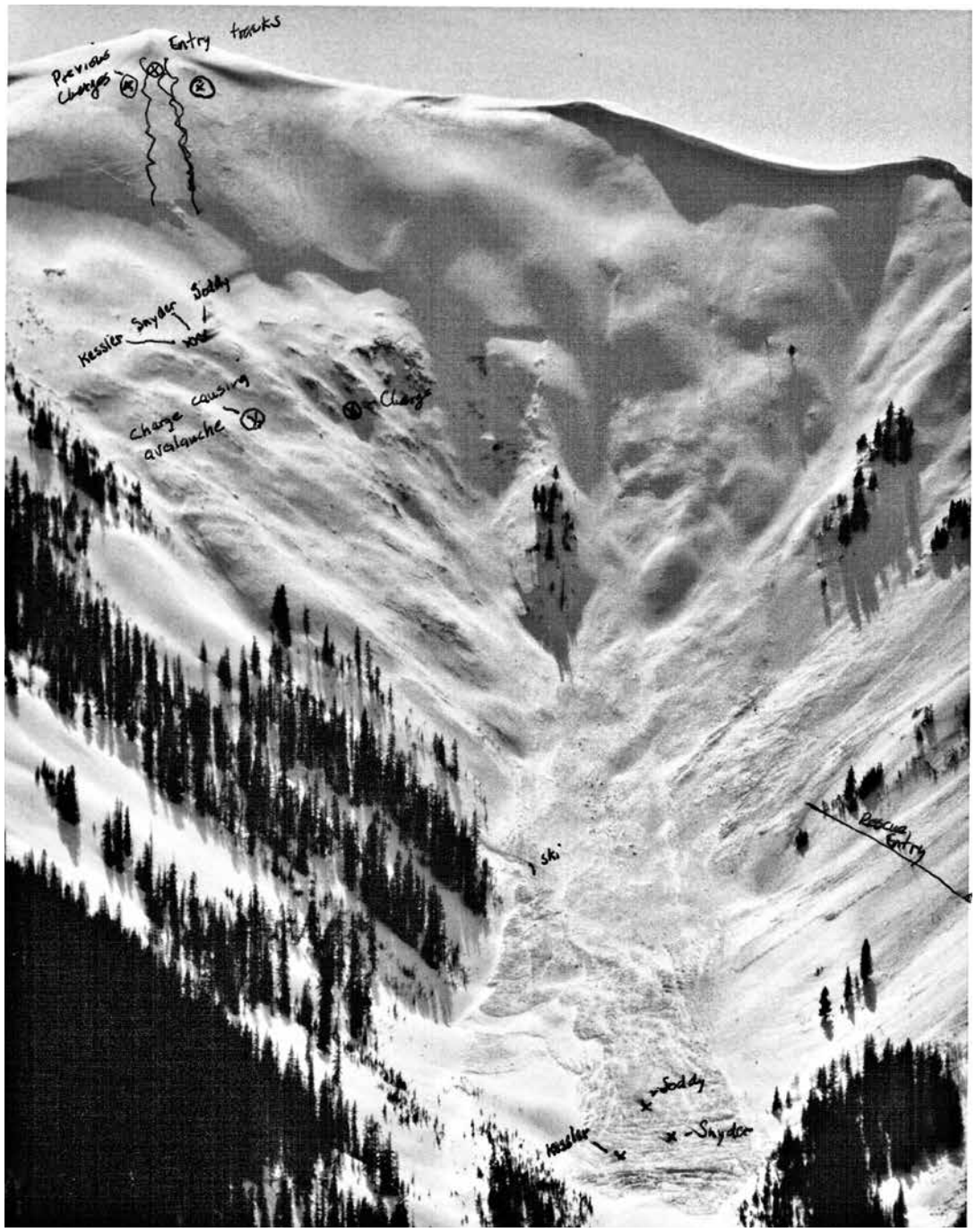
One of the three patrolman caught that day in the slide, skiing down the Bowl from the top through the upper part that overtook the three while standing on the bench in G-8. Photo was recovered from Kessler's buried camera.

The second shot

As is the case in snow safety, plan changes based upon observed field conditions may be appropriate or inappropriate. In this case, Snyder made a field decision based upon his confidence that he could safely assemble there on the bench with the launcher rather than stage from the north-facing trees. The Hyde Park spotters were not happy that Snyder changed from the plan of throw and retreat. But Snyder's view was that they couldn't reach the desired spots without the launcher and the snow above them had proven stable.

From their position on the bench 30 feet above the March 8 slide-path crown, they launched the first charge into the old slide path to their lower left with no results. The second charge, placed below the bench and above where they safely skied on March 29, was a different story. A soft-slab slide broke off the old crown face below Snyder's team. For a moment the mission was a success in that it cleared out Snyder's pocket in question.

One of the three skiing into the top of the Bowl, day of slide. Photo was recovered from Kessler's buried camera.



Highland Bowl on the day of the avalanche on 3/31/84 taken from Aspen Mountain. The photo shows the charges thrown (Xs), the ski route to the bench where Snyder, Soddy, and Kessler were swept away, and the debris at the bottom where their bodies were recovered. *Photo Doug Driskell*

Since the snow in the Bowl may be considered as one piece of complicated fabric, the year-long stable pack above Snyder's team probably slid like a blanket off a bed, as the lower slide collapsed and pulled.

Rupinski, who now lives up the Frying Pan in Basalt, reflects with long-carried feeling that "for a few seconds the guys probably thought they were OK. Then it looked like a huge pane of glass breaking in slow motion."

And Lembke, who was an army-trained ski patrolman in Germany before Highlands and who now lives in Grand Junction, said, "The three guys looked like dots standing there. Then a fracture came up from their left below them, crossing above them. They disappeared in a big churning snow cloud full of chunks and we couldn't track them."

What happened

After the initial tragedy and rescue, Whip Jones closed the Bowl and no patrollers were allowed back in to study the fracture lines or crown faces. But evidence from previous snow-study files and pictures of the slide path taken that day from a plane paint a picture of likelihood.

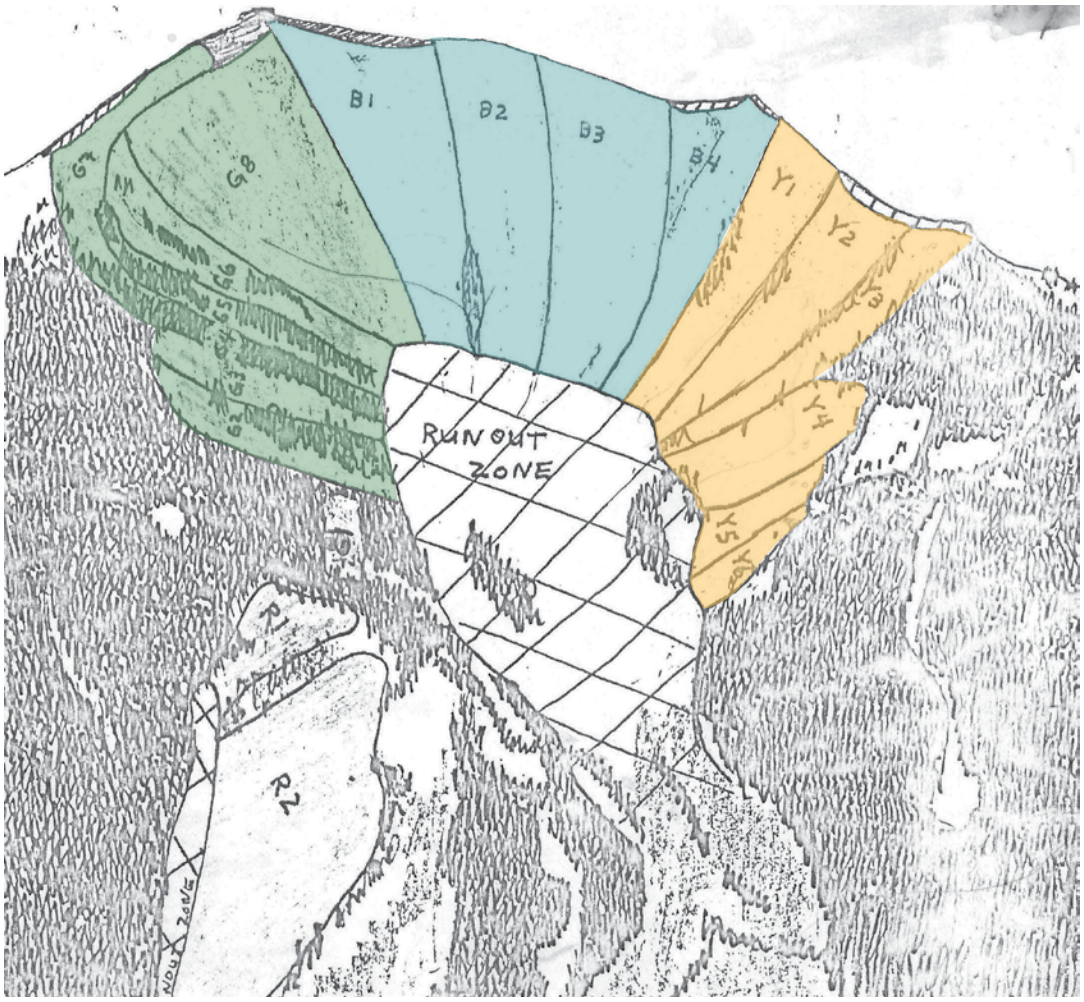
The initial lower slide below the old fracture line slid to the ground on a faceted base layer, noted in Snyder's snow-pit profile dated March 29, 1984, which was why he was retesting those pockets with explosives. Because the March 8 slide path essentially began a new winter as it refilled, base facets remained, while the mid-pack developed a rounding, bonded snow. This created a strong arch-like effect that often keeps Colorado snow in place until, provoked or unprovoked, a slope might slide.

Consensus agrees that the upper, secondary slide that overtook the team slid on a buried surface-hoar layer hidden there in early January. Aerial pictures show that the resulting hard-slab avalanche with boulder-sized chunks slid on a shear plane in the lower mid-pack, about where the January surface-hoar would have been hidden. Remember, though, that buried surface-hoar patches are elusive, and are not everywhere one digs a pit.

The theory goes that the three earlier charges they had thrown above before entering collapsed the surface-hoar into shear planes deep in the pack, like flattened card houses. Since the snow in the Bowl may be considered as one piece of complicated fabric, the year-long stable pack above Snyder's team probably slid like a blanket off a bed, as the lower slide collapsed and pulled.

The combined avalanche in total measured 1,000 feet across. The crown broke 300 feet above the team at an 11,800-foot elevation on a northeast-facing slope exceeding 35 degrees, according to *The Snowy Torrents*. That upper elevation avalanche overran the bench the patrollers stood on.

A note card in the Bowl data file from earlier that year in Tom Snyder's handwriting reads: "The energy of a fracture line can have a thousand times the energy of a skier's weight on the snowpack and can propagate into areas which may appear stable."



Original Bowl map showing the **G**, **B**, and **Y** Bowl zones, which 1970s Highlands patrollers Doug Driskell and Doug Childs named after the colored waxes used for different temperature aspects: green for cold, blue for moderate, and yellow for warm.

The rescue

At 2:40 p.m. Lembke called patrol headquarters, then located where Cloud Nine Restaurant is today, saying there was a "major slide in the Bowl and three patrolmen were caught." Lembke and Rupinski traversed in on an angle and began a difficult zig-zag pattern down the vast debris field, searching with their avalanche beacons. Within minutes, while carrying a metal grain scoop shovel, Lembke picked up the first signal and began digging. Patrollers Jeff Melahn and Pat Fort came into the Bowl from the Loge patrol room and along with Rupinski located the other two signals, as more backup patrollers arrived. Big slab chunks in the debris gave false probing strikes, yet all three signals were pinpointed within five minutes and patrollers began digging.

In those days digging went straight down to the signals. This required a wide hole to manage a deeper burial. Today, preferred technique angles in from below the signal, throwing the snow downhill. Yet busting up avalanche-compacted snow with a mere shovel still requires a mind-numbing adrenalized effort. Records show that patrol recovered Snyder first at 3:15 p.m., five feet down; Kessler at 3:25 p.m., six feet down; and Soddy at 4 p.m., eight feet down. After clearing the victims' airways of snow, patrollers on scene did two-man CPR.

The tour helicopter was not available. Greg Mace of Mountain Rescue alerted the "First Tracks" helicopter out of Marble, which quickly arrived at the bottom of the Bowl. In three trips, a different patroller doing one-man CPR in the helicopter accompanied each victim to Aspen Valley Hospital, where all three were pronounced dead of massive traumatic injuries. All patrollers were out of the Bowl by 5 p.m. and at patrol headquarters for debriefing. That evening they gathered at patrol supervisor Dick Merritt's house for food and drinks, and to begin the long process of reflection.

Second chapter

Chapter one concluded, and like hallowed ground, the Bowl remained closed until 1988, "when we first started tiptoeing in there again" said Jeff "O.J." Melahn, today's head of Aspen Highlands Snow Safety. "We learned that even stable starting zones can be triggered remotely."

With today's early season bootpacking crew, along with systematic application of explosives and continuing skier compaction, "We disrupt every layer and shear plane wall to wall from the ground up, beginning with the first snowfall. Our goal now is to try and preserve every flake that falls, versus flush and refill," Melahn said.

Chapter two began in 1993 when the Aspen Skiing Co. bought Highlands. The Bowl held marketing value not only because of its splendor but because of the emerging popularity of radical skiing terrain. Patrol Director Mac Smith had already led the effort to open Steeplechase and Olympic bowls, and he eyed Highland Bowl next. Patrollers Melahn, Kevin Heinicken, and Peter Carvelli became the new Bowl keepers, who took Bowl science to the next level. They opened the Bowl gradually between 1997 and 2000, with a full public opening in 2002-2003.

Upon reflection, J. R. Rupinski concludes, "Opening the Bowl happened in stages as it should have. Just stand at the bottom and watch all the smiling faces coming out of there." Though some say that the innate sacredness of the Bowl deserves less traffic, those privileged to enjoy the Bowl experience now might reflect on how to "pay forward" their exhilaration to help others, in honor of Tom Snyder, Craig Soddy, and Chris Kessler. ▲

Historical accuracy department:
Settled fact documents that Highland Bowl and Highland Peak were named in the early 1880s by citizens of Highland City, a mining town in the Conundrum valley below often hammered by avalanches. "Aspen Highlands" ski area opened in 1958. For historical accuracy, the distinction remains preserved in Cooney's telling of the Highland Bowl story. Hip Aspen locals say Highland Bowl, while unwitting revisionists say Highlands Bowl.

We F*#%ed up

Photo Grant Gunderson

We F*#%ed up

BY GRANT GUNDERSON

On April 4th, 2018, a skier named Kirsten Rowley and I were up at Mt. Baker on what started off as a high overcast day with a few sun breaks. We got to the top of chair 8 and decided that we would go for a mellow tour out the arm and ski the Heli Line. With the occasional sun breaks we figured that if we happened to see something that looked good and had light we would stop and maybe shoot a turn or two on the way, but our main intention was to simply go for a mellow tour to get some exercise.

The day before we had been freeskiing together all afternoon along with another friend. The new snow appeared to be fairly well bonded to the crust from earlier in the week and, despite ski cutting some steeper rollovers, we did not have any slide activity, so we figured that the new snow was pretty well bonded.

So we started our tour out the arm with some knowledge of the conditions from skiing the previous day and following the weather from the last week. When we reached the bench above the sun cliffs we saw that an area that locals call Hollywood Spine looked really good with filtered skim light. We stopped, talked about the line, and about the stability. We both thought the slope was ok, especially after seeing other groups ski bigger steeper lines without incident. We chatted about what to do in case it did slide and discussed how I would spot the run from the top of sun cliffs where I could easily see the entire slope and runout, and easily and quickly make it down in case something did go wrong. I also reiterated that I didn't want her to feel like there was any pressure to ski it because I had my camera gear, and that if she changed her mind and didn't like it, we would just move on and stick to the original plan of heading out to the Heli Line. We double-checked that we had good radio communications and she skinned over to the top of the line. While Kirsten was getting into position, pulling skins and getting ready, the line was receiving some very filtered indirect sun, despite the cloud deck that had started to lower; a few snowflakes even floated around in the air. There was a slight but cold breeze, enough that we were not warm while skinning, and the snow felt cold and soft, and at least where I was, did not feel like it had any slab to it.

> "Within three-tenths of a second the slide propagated to nearly 300 feet wide. The crown was 12 inches deep. Luckily she was able to ski out of it, exactly as we had discussed previously."

On her third turn the slope cracked above Kirsten. Within three-tenths of a second the slide propagated to nearly 300 feet wide. The crown was 12 inches deep. Luckily she was able to ski out of it, exactly as we had discussed previously. The debris finally caught up to her in the flat runout well past the bottom of the slope and partially buried her to her waist.

After this incident we discussed what happened, her decision to not pull her airbag (and why we think it was the right one in this case), what we did right prior to the incident (had a worst case scenario plan), what we did wrong (instead of spotting her with my skins still on, I should have pulled them. Even with my skins still on I have no doubt I could have still quickly skied down to her to perform a rescue if needed). We discussed how it is safer to be in group of three or four in case something goes wrong in the backcountry. Most importantly we chatted about how we got fooled into thinking the slope was going to be ok and how that only this slope slid when none of the larger and steeper lines that were getting skied that morning did. We believe that we got fooled by how much effect the filtered sun was having on this slope, since it was April, when the sun is stronger than it feels. This was compounded by the cold breeze that led us to believe that it was colder than it was, and was still keeping the snow cold on our skin up.

It goes to show why it is always smart to discuss a worst case scenario and have a plan even if you think a slope isn't going to slide. This is also a good reminder that a slope can propagate farther then you expect. At the end of the day, we are making best guesstimates about if a slope will slide or not based upon the best knowledge that we have at the time. No matter how careful you are in the mountains, sooner or later the odds are going to catch up with you and you will have to deal with a close call or an accident. Kirsten and I hope this will help serve as a good reminder for others to always discuss the line you are looking at with your group, to have all of your safety gear and to always discuss what to do in case things go wrong.

Anyone that spends the majority of their time in the mountains is going to have a close call at some point. We are all human and we all make mistakes. Knowing this is why I have always tried to stack the odds in our favor in case something goes wrong. For example, everyone that I ski with always uses one of my radios pre-programmed with the local rescue channels, ski patrol, local helicopter operations etc.

Notes on Airbag

A lot of people have asked about Kirsten's decision not to pull her airbag. Kirsten and I discussed this after the incident; she was concerned that pulling it would have slowed her down, impeding her ability to ski out of the slide. Since she was on top of the slide and managed to get ahead of it while skiing out, I trust that she made the right decision in this incident. That decision was hers alone to make in the heat of the moment, and everyone in that situation is going to have to make that call for themselves.

People tend to have too much confidence in airbags. They do work and a close friend of mine survived an avalanche that killed three others because she used her airbag; however, I have been told by many people with way more knowledge than me about the physics behind airbags that they are only effective if you are not at the bottom of the slide path when engulfed by the slide.

Skier's Perspective

BY KIRSTEN ROWLEY

I really appreciate that our incident is being shared to help increase awareness and respect for safety at all times in the mountains no matter the conditions. Avalanches should always be highly evaluated; they are terrifying and nothing to be proud of experiencing.

Grant and I had planned several days out up at Baker to shoot some photos. That Thursday morning, after discussing the weather, we intended to have a day to go get some good turns in and put away the camera. We figured if something seemed worth taking the camera out for, we would, but we were focused on a fun, safe hike out on the arm for a good ride on Heli Line down together.

Grant mentioned in his notes that, as we were hiking up, a line that locals call the Hollywood Spine was looking good to ride, I have been wanting to ride this ever since my first year visiting Baker but conditions had never offered me the chance. Considering the conditions and stability of neighboring lines others were riding that day, Grant and I both agreed that it seemed to be stable and a good opportunity to ride the line.

As said in Grant's notes, and what I see as such an important highlight, is that we had a full discussion about the line's conditions, how to ride it, different what-if scenarios, and double checks on all of our gear before I headed to the top of the spine.

> "We had a full discussion about the line's conditions, how to ride it, different what-if scenarios, and double checks on all of our gear before I headed to the top of the spine."

1. In my experience I feel like a lot of people forget the importance in detailing a double check and going through a safety checklist before anyone rides down any sort of slope, hikes across a snowfield, or leaves the parking lot. Especially important is communicating with your partner/team so that everybody is on the same page. I feel that the fact that Grant and I had this conversation prior to dropping helped insert an emergency scenario in the back of my head, so that I was ready to respond if necessary. We discussed response strategies for both me as the skier and for him as the spotter.

   I hiked up to the top of the line away from Grant; he was staged in a safe area with good visuals. At the top I double-checked my gear and thought about my line and how I wanted to ski it, I also pursued a separate mindset of how I would ski the line if things were to go south. I do this every time before riding a line no matter where I am and try to put myself in the mindset of the best case scenario as well as the mindset of the worst.

2. I used to downhill ski race on some big runs up in Canada and before pushing out of a start gate onto two miles of bulletproof ice, where I anticipated reaching 75mph, I

was always a little bit terrified, aggressive, focused, and calm. As my stomach dropped, I would focus on balance. I have always figured that balance would represent a quick mindset to switch into should a run ever actually shift into "oh shit" mode: I'd try react quickly but also remain calm. I try to imagine and practice what that mindset would feel like. Before dropping, I switch into "go" mode, which focuses on making everything going as planned, riding a safe line with smart balanced turns that I feel comfortable with.

After all my gear was good to go I radio checked with Grant and called in my drop. I was stoked and ready for some good turns- kicked up some snow and pushed off. After four turns into the rollover, I was just situating over the front of my boot for the steeper line and I saw the crack. Right away my heart dropped, and quickly I switched into my other mindset, reacting, as Grant and I had discussed, to ride the spine straight down if a fracture appeared midslope. I went into downhill ski race mode, calm and focused, staying on top of the spine and pointing straight.

3. There was not a lot of time to think in that moment at all. This is why it is so-so-so important to talk about and think about what-if scenarios before dropping in.

As I reached the bottom of the slope I was slowly caught back in the debris and pulled to a stop and buried upright to my thighs. Right away I could hear Grant through the radio, urgently telling me to remain standing upright and strong in case any debris was to continue to push from behind.

Everything stopped pretty quickly and I felt pretty freaked out about what had just happened. I also wanted to get out of that zone as quickly as possible considering surrounding slopes. I confirmed with Grant over the radio that I was ok and we agreed I would ski out the gates below and ride back up the chair to meet him up top, then we'd make our way back to the Baker Lodge and call it quits for the day. We were both pretty shook up.

We messed up by not doing a re-evaluation of the effects of the sun break that occurred during the time that I had left Grant at his visual spot and was hiking up to the top of the line. This direct sun hit could have changed the conditions of the snow within the short time it took me to hike to the top.

The big takeaways are the importance of doing a detailed double safety check with partners, and to assume that things can always go south no matter how solid the conditions have been forecasted or how stable slopes may seem. We owe so much respect to the mountains and what Mother Nature can do. At the end of the day she's in control of what goes right and what goes wrong; all we can do is make the safest, smartest decisions possible.

Grant and I hope that others can learn from our mishap and that our story encourages everyone to be as safe as possible on the snow this winter. ▲

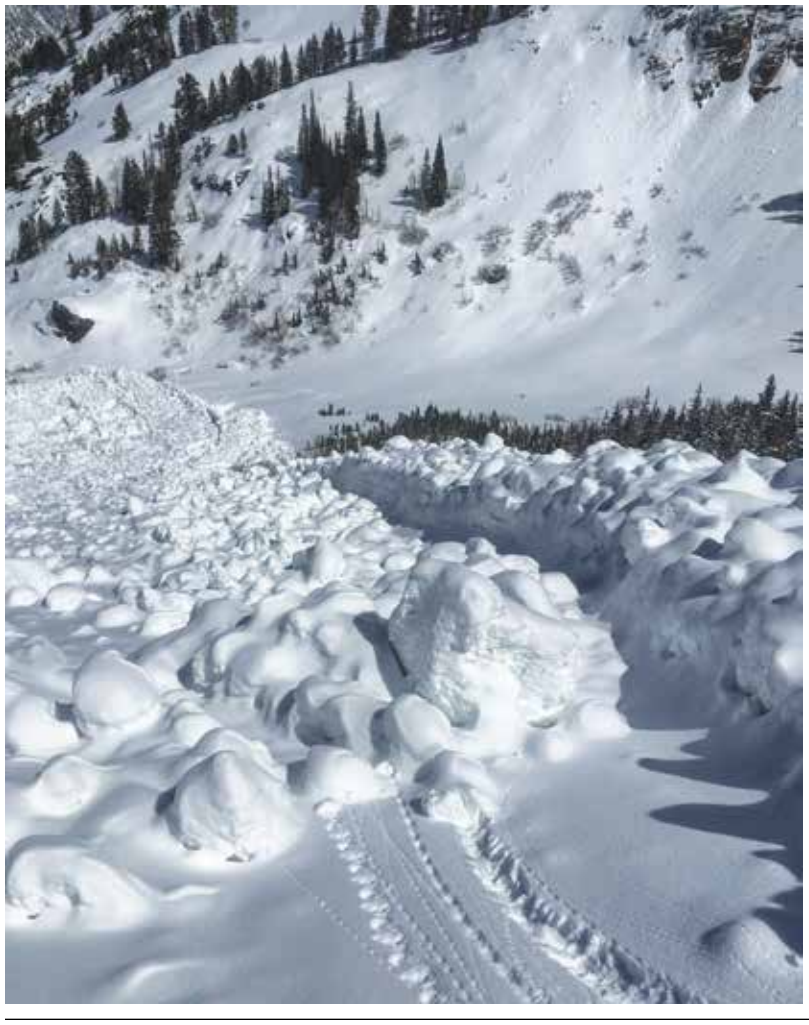
POLICE LINEUP

These glide slides were on a run called the Diving Board in Broads Fork, which is an east-facing slide path running off one of the SLC Twins (twin peaks).

This is one of the main areas where we get glide avalanches in the central Wasatch. If I remember correctly, it had been a warm week, culminating in a high elevation rain event. The rain and snowmelt filtered down through the snowpack, lubed up the persistent weak layer down close to the bottom of the pack, and triggered the slide. There was also some glide activity on Bonkers, the next run north of there.

The day I was there things had cooled down and there was a thin coat of powder on top of the frozen debris. These are shots from that day and also some shots from the same place but a different day after another high elevation rain event caused more large glide slides to the ground.

—Mark White



201718 season stories

the state of the avalanche industry

National Avalanche Center

Nationally, the winter of 2017/2018 was characterized by a consistently cold and wet northerly flow. This pattern left Washington, northern Idaho and Montana with above average snowpacks, while Oregon, California, and New Mexico came in well below average. The areas on the cusp of north and south endured periods of drought followed by intense storms and interesting avalanching.

Here is a quick snapshot of US avalanche center activity for the 17/18 season:

- **90** full time (seasonal) workers - ~60 agency and 25 non-profit.
- **20,000** volunteer hours.
- **6.5 million** advisory/forecast views.
- **12 million** unique page views by 1.6 million unique users.
- **35,000** students attended classes or lectures.
- **90** Weather Stations owned and maintained.
- **30** days with avalanche warnings.
- **25** avalanche fatalities (compared to a 20-year annual average of 27). This marks the fourth consecutive year where US avalanche fatality numbers have been at or below the 20-year average.

This marks the fourth consecutive year where US avalanche fatality numbers have been at or below the 20-year average.

Increased availability of technology is creating new opportunities for avalanche centers. Much of the NAC's workload last season focused on Avalanche.org, which operates in a partnership with the American Avalanche Association. Avalanche.org allows us to showcase and promote the work conducted by avalanche centers and educators around the country. Additionally, we use it to develop and house collaborative tools such as the national avalanche danger map, the Avalanche Warning Platform, and the Mountain Weather Station Platform. For example, more than 20 independent forecasting operations contribute information to the national avalanche danger map!

The combined effort of the entire avalanche community is saving lives. Thanks to everyone for the hard work and here's to a good season in 2018/19!

—Simon Trautman and Karl Birkeland

Gallatin National Forest Avalanche Center

This season we made out like bandits. **It snowed 130 out of 165 days**, our biggest snow year in southwest Montana since 1996-1997 with depths averaging 120-160% of normal. On September 16th winter arrived with a foot of snow in the mountains and on the 17th a skier triggered the first avalanche of the season. On the 19th, after continued snowfall, Alex issued the first avalanche information bulletin, the earliest in 28 years of operation. We issued 17 bulletins in the fall and started daily avalanche advisories on November 24th which ended 136 days later on April 8th. Because of the large snowpack we issued 9 more in April, making this our longest season by far. Steady snowfall hindered the development of lasting weak layers that can form with a shallow snowpack or during clear weather, two things that were in short supply. We issued avalanche warnings 7 days during the most dangerous times compared with 13 warnings the year before.

The country's first avalanche fatality occurred in the southern Madison Range on October 7th when two skiers were caught on the flanks of Imp Peak, killing one, a beloved local. **This was the second earliest avalanche fatality in the U.S. in 50 years.** In January a snowmobiler was killed near Sage Peak, and two other sledders were killed in separate avalanches in the Centennial Mountains, just outside our forecast area in Idaho. The season ended with an avalanche fatality on April 14th involving a solo skier on Saddle Peak, the sidecountry of Bridger Bowl. Having the season bookended with tragedies made the winter especially long and taxing. Fifty-two avalanche incidents (about average) were reported in our forecast area that resulted in **18 caught, 3 injuries, 10 partial burials, 9 full burials and 3 deaths.**

Our biggest challenge at the avalanche center was not the snowpack. Persistent weak layers were in short supply and avalanche incidents mostly involved new snow following storms and avalanche warnings. The question, "If a blustery snowstorm buries a surface hoar layer, is the avalanche problem new snow, wind slab, or a persistent slab?" provided fodder for mental gymnastics, but the real challenge was elsewhere: educating the public.

The population is growing at a fast clip with people moving here to recreate, many being first year students at Montana State University. Four thousand amped college freshman along with adventurous high schoolers are ripe for avalanche education. In November we launched a 4-part video campaign titled "Get Avalanche Smart," targeting this audience to take an avalanche class. The series had 58,600 views and helped increase enrollment in our MSU class Introduction to Avalanches with Field Course by 50%. Over 500 people attended two nights of lectures and a field session. We also filmed "Dashboard Talks," seven informal conversations about avalanches as we drove home from the field. These were viewed 33,000 times. As more and more people move into southwest Montana, it's our duty to reach out and educate them about the backcountry.

This season **we taught 134 classes that reached 5,300 people**, a record number. We try to accommodate all requests for classes, no matter the age or user group: motorized or human-powered. We have a roster of 30 instructors, many are outdoor professionals and all are competent.

We continued to lean heavily on videos to notify the public on what to look for in the snowpack and what to do about it. This season we made 121

The rest of the country has a hard time feeling sorry for Montana and how deep they had to dig their full profiles last winter. A snow ranger from Cooke City and a member of the USGS completed the daunting task of trying to find the ground under more than 10′ of snow. This pit had a depth of 133 inches. Instabilities through the season were typically confined to 2-4′ of new and wind blown snow with no deep widespread weak layers. *Photo M. Dixon*

We had a big early season avalanche cycle just after the New Year in the mountains around Cooke City. It was the most widespread natural avalanche cycle I've seen in my 10 years of living here, and interestingly most of those avalanches were happening mid slope, rather than starting in the upper elevation, wind loaded areas like they usually do. They were failing on faceted snow that formed in December and rested on a Thanksgiving M/F crust in some places.

Next, some surface hoar formed early in that second week in January, and was overlain by another storm with a little bit of wind, which soon tipped the scales. I went up to investigate the slide a few days later, and estimated the crowns to be approximately 3' deep in the upper section, and 8' deep in the lower section. I didn't do a pit profile, but those depths most closely correlated with the early January surface hoar on the Thanksgiving M/ F crust. The avalanche wrapped into the adjacent north-facing bowl also (lookers left), and was approx. 2000' wide in total. *Photo Beau Fredlund*

videos, the most ever. These were viewed a total of 407,789 times: 238,942 on YouTube, and 168,847 on Instagram. A person who consistently watched our videos without reading a word of the advisory would still have a good understanding of the snowpack. Between the three GNFAC forecasters, we had 115 field days and made a video on almost all of them. The videos are posted the same afternoon so people can think about the snow before the next day's outing.

Social media is a game-changer, unbelievably effective at allowing us to reach thousands of people a day. We used these platforms more aggressively this season in order to inform people about our avalanche concerns. Every morning we would post to Facebook and Twitter and again every afternoon after our field day, including Instagram. The number of followers grew rapidly: 9,147 on Facebook, 7,611 on Instagram, 3,006 subscribers on YouTube and 2,004 on Twitter, a 35% increase from last winter.

This season our website was redesigned to make it mobile-friendly and easier to get information. We added "Regional Conditions" pages, a one-stop shop of weather, snowpack, pictures, videos, and snowpits for each mountain range. The upgrades worked and **7,559 people a day received the advisory**, 6,011 by email and 1,548 via the advisory page, a 60% increase from last season. Contrary to popular belief, people spend 2 minutes and 50 seconds reading the advisory page (according to the all-seeing Google), about as long as it takes to record it for our phone line.

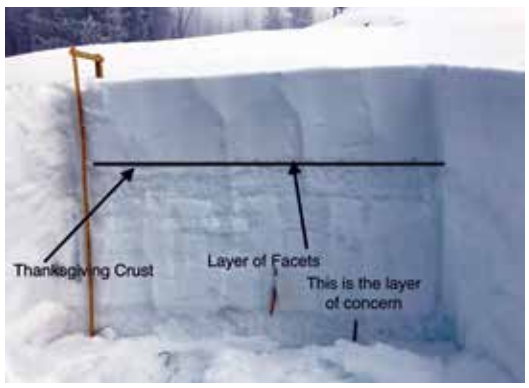
We were mentally and physically worn down after a season of record snowfall, and a record number of avalanche advisories and education classes. Luckily this did not translate into a record number of avalanche incidents. As climate changes and weather patterns remain confusing, who knows what next winter will bring. Regardless, the winter of 17-18 is one we will remember.

—Doug Chabot

West Central Montana Avalanche Center

The season started October 06 2017 with reports that the first fatality of the season occurred in Montana. The season was shaping up nicely when, at Thanksgiving, the rain came to 10,000 feet, creating a crust in all of our ranges. We then got a small amount of snow on this crust and experienced cold temperatures and limited snowfall, so that new snow faceted, laying groundwork for a Persistent Slab problem that would be with us for most of the season.

Turkey Day crust in early season.



The first test for this layer was on December 19th when we received 2.2 inches of SWE, prompting the first warning for the season. A Pineapple Express on December 29th brought us a 3-day Avalanche Warning that lasted until the new year. During this Pineapple Express we saw one of the largest natural cycles in recent memory for our whole advisory area. We tracked this layer until late February when we finally put it to bed.

We also struggled with Turkey Day crust and facets for many months; it was tough to get the message to our community without it becoming stagnant. Our main difficulty was knowing when to go from a Persistent Slab to a Deep Persistent Slab. We never made the move as we didn't want to confuse our audience by changing the problem (The crust and facets now buried deep in our snowpack). So we concentrated more on our discussion and travel advice rather than the name of the problem. The take-home point for our area: keep it simple and write the advisory for your Mom who does not even recreate in the backcountry.

Highlights

- 52 advisories, 17 updates, 6 warnings
- We had **no fatalities** in our advisory area with a very reactive snowpack and very few close calls.

- Two AIARE mechanized level 1 courses partnering with the Mountain Riding Lab. These courses had the new AIARE mechanized curriculum and were the first courses offered in Montana.
- We partnered with our local brewery Big Sky Brewing and had a weekly **Beers with Forecasters**. This event was an informal way for people to get information on education and current snowpack conditions.
- Our Friends group was able to **reach 2851 participants** from KBYG, Level 1 courses, and Awareness courses.

Outlook for Next Season

Next year we are looking forward to going to a seven-day advisory.

—Travis Craft
Director, WCMAC

Bridger-Teton National Forest Avalanche Center

The winter season arrived early in the Bridger-Teton National Forest forecast areas. A 12-day storm cycle that began on September 14 plastered the upper elevations with deep snow that would last through the season. Storms in October and early November produced record seasonal snowfall totals and snow depths by November 7. Large slab avalanches with 5 to 10-foot-deep crowns occurred on November 4 and 5.

A week-long thaw with multiple rain events began on November 20. On November 24 heavy rain occurred up to an elevation of 10,500 feet. Temperatures fell back below freezing on November 28. Small storm systems deposited around 20 inches of new snow on the November rain crust during the next 9 days. Ten days of dry weather ensued. These circumstances resulted in the creation of a persistent weak layer of faceted snow on a hard rain crust. This problem layer would be the bed surface of many avalanche events during the next two months and some large wet slab avalanches in early May. Avalanches that occurred on this "December Drought Layer" (DDL) were characterized as wind slabs for the first three days of new loading, as persistent slabs for the following three weeks, and as deep persistent slabs into March.

An extended avalanche cycle involved many days of considerable and moderate hazard with dangerous or consequential avalanche hazards. With close calls involving experienced local backcountry users occurring every other day, message fatigue was identified as an important challenge. Statements such as **"Your terrain selection choices could end your life today"** were employed in the text fields of our daily avalanche hazard advisories. These strong statements were effective descriptors of the situation and were well received.

The DDL was the bed surface for two fatalities that involved riders on snow machines. A third person riding a snowmachine died in a wet slide on April 22. An alpine skier who left a resort boundary died in an avalanche on February 17.

The season ended with over **550 inches of total snowfall** in the Teton Range, over 400 inches on the Continental Divide in the Togwotee Pass area and up to 350 inches in the southern portion of our forecast region. Daily average mean temperatures were 6 to 7 degrees above normal in December, January, and during the first two weeks of February. Temperatures were near normal from mid-February through mid-April and were above average from mid-April through mid-June. Rain events were common below an elevation of 7,500 feet in November, December and January. This scenario kept snow depths at near record lows in the valley until late January. Very little snow accumulated at the upper elevations after mid-April. For this reason, the maximum snow depths at an elevation of 9,500 feet peaked on April 13, which is about one month earlier than normal.

Two new products that were created in partnership with Patrick Wright and Toby Carmen of Inversion Labs were available on the Bridger-Teton Avalanche Center web page during the 2017/18 season. Both products use web-based technology to display weather and avalanche data. Historical graphs display 44 seasons of weather data and avalanche events. This product was popular with avalanche educators and forecasters. The snowpack tracker tool displayed avalanche events, weather data, and daily avalanche hazard ratings for the 2017/18 season in a graphical format. This product was well received by backcountry users, forecasters and avalanche educators. Both of these products were developed with date range selection functionality and data from multiple weather stations. These products use 24-hour temperature, snowfall, and wind averages. We hope to develop a new product for the upcoming season that will display hourly data for these parameters.

Avalanche education efforts were conducted with financial support from the State of Wyoming. Avalanche awareness classes were provided to multiple communities within Wyoming that are outside of our forecast regions. These efforts included teaching avalanche rescue techniques developed by Manuel Genswein. Contacts to the center for avalanche hazard information increased during the 2017/18 season and exceeded 2.2 million.

—Bob Comey, Director, BTNFAC

West Central Montana: Today's snow surface is tomorrow's buried layer. *Photo courtesy West Central Montana Avalanche Center*

Bridger-Teton: Large wet slab avalanche that released naturally in the Little Tuckerman's Bowl area of Mt. Glory on May 7, 2018. This dangerous slab avalanche is believed to have failed on the December drought layer and occurred after temperatures remained above freezing for several nights. *Photo John Fitzgerald, WYDOT*

Flathead Avalanche Center

It was an exciting winter to join the Flathead Avalanche Center! A poor basal snowpack structure and momentous snowfall made for a challenging and memorable avalanche season. The constant stream of Pacific Northwest storms over persistent weaknesses contributed to 13 avalanche fatalities in Washington, Montana, and Idaho, one of which tragically claimed a member of our community in the Flathead Valley when a solo skier went missing during a storm cycle in mid-February. Despite extensive search efforts, his body was not recovered until May 12, 2018.

Our forecast team of Zach Guy, Mark Dundas, and Chris Bilbrey all sprouted a few grey hairs during this busy winter. By mid-April, the Flathead River Basin snowpack reached 152% of average. The heaviest rain event occurred on Thanksgiving and the longest dry spell occurred during the first two weeks of December. These two weather events laid the crusty foundation for a tricky deep slab problem that plagued higher elevations well into February (*See TAR 36.4 for more photo and details*). Deep slab avalanche activity became increasingly larger and more fickle as the season progressed, with **several slides reaching historic sizes** during a culminating rain event on February 8th.

Our biggest challenge was the decision to remove deep slabs from the problem list after two months of sporadic and spine tingling activity. Our decision to remove the problem by late February (in hindsight, probably two weeks too late), was based on an abrupt halt in activity within our advisory area and a decline in explosive and natural activity at the regional scale. Data sharing with our Canadian neighbors was incredibly valuable. The complexity of assessing a spatially variable layer squished 9 to 12 feet deep was confounded by false public reports of deep slab avalanches continuing to fail through late February. The crowns from the February 8th cycle were so large that they appeared to be fresh through several subsequent storm cycles. Mapping and cataloging photographs of deep slab crowns, along with a good pair of binoculars, were useful tools for handling misleading observations.

Thanks to **nearly perpetual snowfall** from mid-December until March, we had few other long-lasting weak layers this season, and the bulk of other avalanche activity was the result of direct action storm, wind, or wet avalanches. The intensity and frequency of storms faded into spring, giving way to more yellow and green hues in March and April's advisories.

The public applauded improvements to our advisories, which included **substantial increases in the number of field observations**, photos, and supplemental videos. Outreach efforts are making a clear impact: website use continues to increase while **our social media audience exploded.** Even as we expand the number and level of avalanche classes, attendance is brimming at capacity. Thanks to everyone who contributed time our resources to the FAC. We are excited to the keep the momentum rolling next winter!

—Zach Guy
Director, Flathead Avalanche Center

Flathead: Boaters beware! A D4 glide avalanche off of Heavens Peak sent avalanche debris chunks across McDonald Creek in Glacier National Park on May 9, 2018. *Photo Adam Clark*

Flathead: This snowcat was buried by a slide while grooming a snowmobile route in the Whitefish Range on the night of February 6th. Everyone was OK. *Photo Chris Bilbrey*

Idaho Panhandle Avalanche Center

Weather and Snowpack

The winter of 2017/18 started off early and ended late up in North Idaho! In mid-November the faucets turned on (both literally and figuratively). The month started off with three inches of snow on the ground and accumulated 42 inches of HS by November 21, which made for a great start to the winter season. As soon as we got used to awesome powder conditions though…it started to rain, and I mean rain. From November 22–27 we received 4.2 inches of SWE. Not only did the rain knock down our HS from 42 inches to 21 inches but it created a **deep instability** (Thanksgiving crust) that we ended up dealing with all season (*see cover photo of TAR 36.4*). After November 27th it got cold and started snowing again. This set up an interesting foundation to our snowpack. On one hand it created a great vapor barrier to keep our basal instabilities in check but on the other hand it became a firm, smooth slide surface that was quickly buried intact. For the first part of the winter we would dig down to the Thanksgiving crust to monitor it. Eventually it became so buried that we stopped digging to it and just started calling it a 'deep instability' instead of a 'persistent weak layer'.

As we got into the middle of the winter, snow conditions remained above average and we started to isolate the Thanksgiving crust deep in the snowpack. Even though we always had it in the back of our mind, our concerns started to shift to other instabilities closer to the surface. During the week of January 22, the mountains in **Northern Idaho received 60+ inches of snow** and created a very tender storm slab. On January 25th we issued an Avalanche Warning because of the conditions created by the new snow.

Then, on January 28th Schweitzer Ski Patrol was conducting morning avalanche mitigation which remotely triggered a slide that bypassed all the other instabilities in the snowpack and pulled out on the Thanksgiving crust. The avalanche was classified as an HS-AE-R3-D4, **the crown was 170 to 300 cm deep by 620' wide**. We also saw and heard of two other big slides in the backcountry that happened during that same time in the northern Selkirks.

Between a complex snowpack and awesome skiing conditions, this season was one for the history books. The snowpack peaked on April 18th In the Cabinet Mountains where it was measured at 184 inches deep which was 169 percent of average. Even though we had multiple reported avalanche incidents, there were no fatalities in our forecasting area. The 17/18 season was a considerable (no pun intended) success on many levels. I was particularly excited about the strides we made with our users. This was a great season to connect more with a rapidly growing user group. We're working hard to tap into all the different winter riding groups; we strive to give them the best information we can.

Education and Outreach

IPAC had a momentous year growing our education program. Here are a couple of highlights from this season:

- We started an avalanche awareness series that we called '**Snow Pit Chats**.' Our idea was to get away from the cookie cutter avalanche awareness class and try to inject some fresh energy into our classes. We tried to talk about current issues in the avalanche world, relevant snowpack discussions and included keynote speakers. Beer and pizza helped pack the house as well! Thank you to our Snow Pit Chat keynote speakers: **Bill Williamson, Liam Fitzgerald and Mark Yancey**.
- With the growing interest in backcountry, IPAC saw a need for more advanced avalanche training. This past season we taught three AAA Avalanche Level 1 classes. Because of the classes' success, we plan on growing the program next season with a couple more Level 1 classes and the addition of a Level 2 class. We're excited to see such an interest from our local backcountry users.
- IPAC partnered with Silver Mountain Resort to create a '**Backcountry Weekend**,' where Silver Mountain hosted a weekend focused on avalanche safety and making good backcountry decisions. The weekend's activities included avalanche awareness ski and snowboard tours, transceiver training, shoveling competitions, uphill downhill ski and snowboard race, and a party. It was a big success. We look forward to seeing it grow next season.

Additional Highlights

- Thank you to the Idaho Parks and Recreation for donating a snowmobile to us last winter. With an aging fleet of IPAC snowmobiles, the addition of a newer, sleek rocket of a sled helped us out a bunch!
- Thank you to our local ski areas for their partnership and support: **Lookout Pass Ski Area, 49 Degrees North, Silver Mountain, Spokane Mountain and Schweitzer Mountain Resort.**
- This past winter **we added a third forecasting zone** to IPAC. The Kootenai zone, which previously reported conditions through the Flathead Avalanche Center, switched to report through IPAC. It was a change that made sense to both avalanche centers. Even though the Kootenai zone is in Montana, it shared a border with one of the current IPAC zones and dealt with similar avalanche problem. Thanks to our forecaster Ben Bernall for facilitating the zone switch. Now we must figure out if we need to change our name since one of our zones is in Montana!

—Jeff Thompson

Sawtooth Avalanche Center

Our "December Drought Layer" was buried on December 19th—two days after a complete tear of my ACL and partial tears in my meniscus. To say this season began on uncertain footing is an understatement. Two weeks later, "12/19" was under a 40 cm slab with another 1-1.5" SWE forecast to arrive overnight. The next morning, an Avalanche Warning in effect, I dialed back the hydromorphone hydrochloride in my system to clear the fog just enough to crutch to my front porch and give an interview for the nightly news. I'd be out of the forecast rotation for just under a month and wouldn't get back into the field for the remainder of the season.

Fast-forward to Valentine's Day and another weak layer is disappearing from view. The "2/14" layer presented as a layer of facets on north-facing slopes and a crust/facet combo on more south-facing terrain. Skiers and riders remotely triggered several D1-2 slides as the hardness and thickness of the slab above "2/14" gradually increased. By the end of February, weather models predicted an **Atmospheric River event that did not disappoint**. Two-day storm totals topped 30" of snow and 2.5" of SWE in favored areas, triggering widespread natural avalanches and eliciting a two-day Avalanche Warning. The initial cycle involving "2/14" was straightforward and predictable, but "2/14" had no plans to "go gentle into that good night". **Rage, rage it would, making Dylan Thomas proud**.

Another Atmospheric River event turned the hose onto our southern zones on March 22nd. Weather tools sorely under-predicted precipitation amounts as Bald Mountain received 1.64" of SWE in 14 hours when the forecast called for

Idaho-Panhandle: This photo is from the Jan 28th slide at Schweitzer Mountain, North bowl HS-AE-R3-D4. Another photo of this crown was the cover photo for the April TAR, 36.4. *Photo Jeff Thompson*

0.58" in 24 hrs. Upper elevations experienced another round of widespread avalanche activity with a few slides failing over 6' deep.

However, the most interesting activity occurred near the rain line at ~8,200-9,000'. An impressive wet slab cycle rocked middle elevations of the Wood River Valley but spared similar slopes in surrounding mountains just 10-15 miles to the north and west. After this thorough soaking, it seemed reasonable to assume that the areas which produced these large wet slides were unlikely to produce similar avalanches until temperatures would soar and send another large pulse of water deep into the snowpack in late April and May. So you could imagine our surprise the afternoon of April 6th, when, following a couple days of seasonal, partly cloudy weather, two natural D3 wet slab avalanches cleared hundreds of mature trees from a burned area and stopped just short of a home west of Ketchum. That morning's advisory warned of two nights of above freezing temperatures, but this seemed like tier two info compared to the 2.38" of rain that fell in this same location just two weeks prior.

The Valentine's Day weak layer would ultimately affect our forecast area for over two months, continuing to produce large wet slabs into May. It had a remarkable ability to take a load, adjust to it, and linger—releasing both dry and wet slab avalanches over several large storms and multiple hot spells. As resilient as "2/14" was, I could say the same for our crew here at the SAC. How would your organization hold up to losing a forecaster for the year in December? We managed to grind it out, but we feel lucky. Following my surgery, Scott made the necessary adjustments to keep things running as smoothly as possible. Both he and Matt shouldered an increased load of forecasts and education events. Ben returned for his second year as an intern forecaster and stepped up to the plate in a big way, doubling down on field observations and picking up extra forecast shifts. Chris Lundy, former director of the SAC and current co-owner of Sawtooth Mountain Guides, gracefully assumed the position in the forecasting hot seat while I was doped up after surgery. Tight staffing and budget constraints can have a big impact on an avalanche center if someone from your team goes down with an injury. While we hope for the best, it's important to plan for the worst. Scott, Matt, and Ben all deserve a huge amount of credit for being flexible and maintaining the quality avalanche forecast and weather products our community has come to expect.

—*Ethan Davis*

Northwest Avalanche Center

The winter of 2017-18 was dynamic and full of growth at the Northwest Avalanche Center. In general, the weather patterns and snowpack were near historic norms as season precipitation totals approached 100 inches of water equivalent (93" at 4,200 feet on Mt Baker Ski Area and 79" at Snoqualmie Pass 3,020 feet by mid-May). Snowpack depths ended the season between 96-108% of normal at weather stations throughout the Cascades. Mid-winter brought a cluster of tragic avalanche fatalities and associated challenges. Overall, there was much growth in staffing and programs which is propelling the center forward for future seasons.

NWAC grew existing outreach programs and created new ones. **Education grew by 25% as we reached over 7,500 people** in 242 different programs. We saw similar growth across all segments of education programming, including youth and snowmobile programs. A very dedicated volunteer implemented a new trailhead outreach program at backcountry trailheads throughout the Cascade Mountains, where, spread over 10 different weekends over the course of the winter, **NWAC counted over 1,684 users**, collected 898 surveys, and interacted w/ countless backcountry enthusiasts. One Saturday of note, volunteers counted over 200 users (mostly snowshoers) braving a downpour to enjoy the backcountry near Mount Baker Ski Area. Along with snowshoers, motorized users are a group that, like in many regions, we are targeting for future outreach.

NWAC added staff for the 2017-18 season. Long-time Avalanche Meteorologist Garth Ferber retired in late 2017 and was replaced by Robert Hahn. Robert brings valuable experience with the high-resolution weather models. Josh Hirshberg and Dallas Glass were added to the forecast team as Avalanche Specialists. Both have extensive experience in avalanche education, risk-management, and field-based forecasting outside of NWAC. Matt Primomo was hired as a Leavenworth-based observer to round out the crew of seven staff

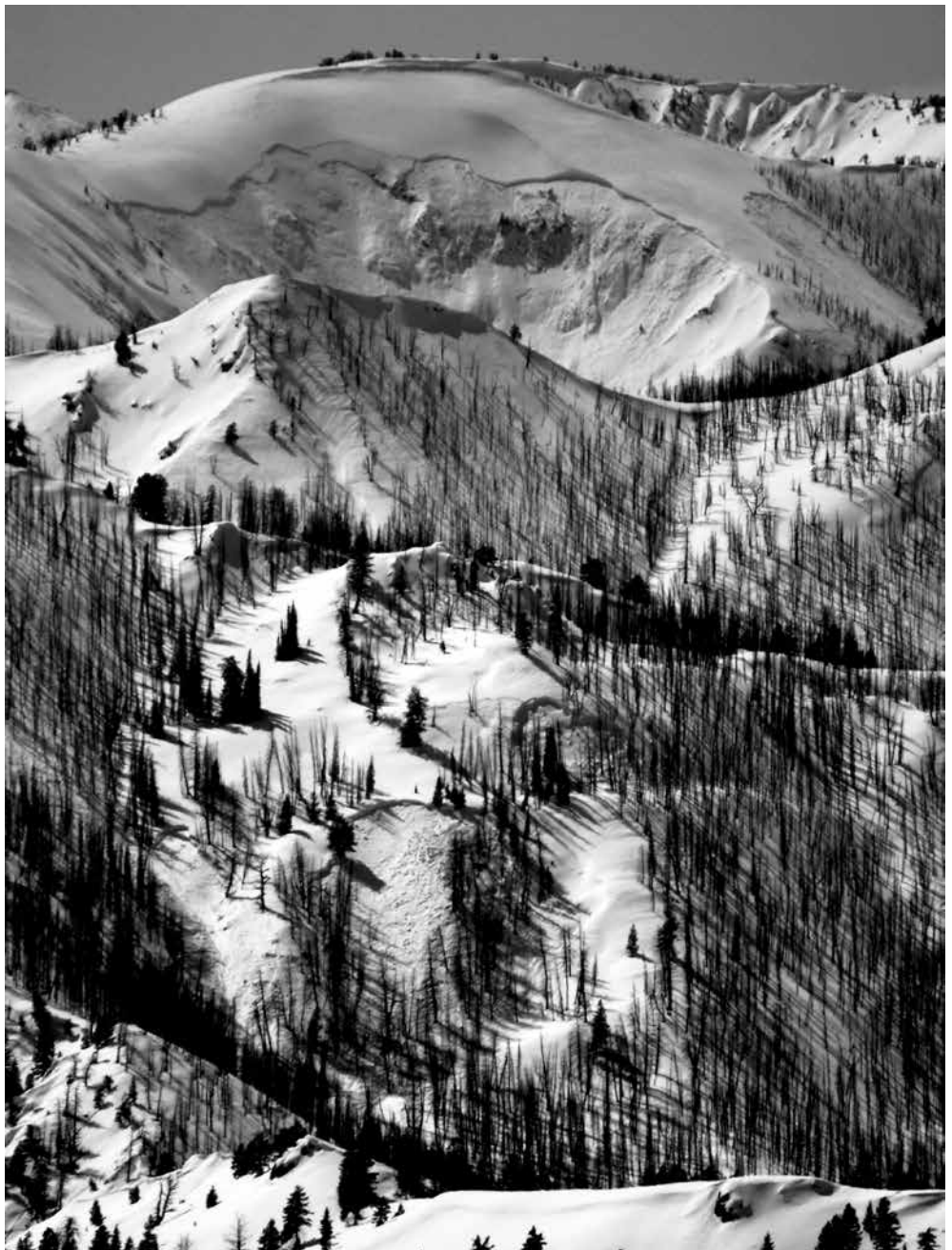
TAR: When did you find the confidence to drop Persistent Slab and Deep Persistent Slab from the forecasts? Was it a certain event or a chain of non-event days, such as 10 days without an avalanche on that particular layer?

Josh Hirshberg for NWAC: Here's a rough and detailed answer: We rallied our field staff to target the PWLs in zones of concern. We hadn't seen evidence of triggered avalanches on the persistent weak layers of concern in well over a week (probably more). In that time observers reported small avalanche cycles involving storm instabilities in layers above the Feb PWLs that had not "stepped down" or involved these weak layers.

We had supporting evidence from tests, probing depth of PWLs, grain size/difference, and degree of rounding (structural indices/yellow flags) showing decreasing likelihood of triggering. The likelihood for PS/DPS had been at "Unlikely" for week. All of this indicated that triggering an avalanche on the PWLs of concern was less than "Unlikely," and we needed to prioritize other problems.

That said we were all confident that the right melt-water event could (and eventually did) result in Wet Slab avalanches on the Feb PWLs.

Sawtooth: Aftermath of 2-2.5" of SWE in 48 hrs. The large crown in the background of this photo is over a quarter mile wide and over 10' deep in places. *Photo Ben VandenBos*



observers. The staffing additions increased NWAC's capacity in critical areas. The team of NWAC forecasters and field observers worked together to forecast dynamic weather systems, track avalanche conditions, deliver helpful travel advice, and respond to accidents when they occurred.

Cold early season storms brought snow to the Cascades on schedule, then were punctuated by a prolonged period of high pressure in mid-December and by major rain events over Thanksgiving and during the first week of January. By mid-January a deep and a relatively average snowpack prevailed. On the west side of the range to the Cascade Crest the height of snow was approaching three meters. To the east of the Cascade crest some slopes held less than 150 centimeters of snow and harbored thick persistent weak layers. January and February were categorized by an onslaught of cold storms with brief periods of rising freezing levels and light rain. The second half of February saw enough clear periods followed by storms to bury up to three layers of near surface facets across much of the Cascades. The February 13 layer (or 18 depending on location) was the most widespread and well-developed. These angular grains averaged 1.5mm in size. In the last week of February, thinner and less widely distributed layers of facets (formed by radiation recrystallization) were buried on steep, sunny slopes.

By February 18 NWAC began forecasting for persistent slab avalanches in most of the zones. From February 25 through March 10 a series of five avalanche accidents resulted in seven fatalities. Of the fatalities, four of the victims traveled on snowmobiles, one traveled on splitboard with snowmobile access, one was on skis, and one was on snowshoes. Including the victims, a total of **13 people were buried** (partially or completely) in these five accidents. The accidents were spread over four different forecast zones and all involved the late February persistent weak layers. This speaks to the widespread distribution of the February PWLs. This cluster of tragic accidents over a short timespan had a major impact on those close to the victims, on the backcountry communities, and upon the NWAC staff. NWAC field staff responded to the accidents with unprecedented coverage. Forecasters and staff observers visited each site within a day of the accident, initiated investigations, and published written reports. When requested, NWAC staff provided support for the associated search and rescue efforts.

The **prolonged period of elevated danger** in February and March brought many challenges. It came at the tail end of a very stormy couple months during which the NWAC staff had worked hard to stay on top of conditions. Forecasters felt an urgent need to provide useful and relevant advice to users during the dangerous conditions. Working in teams, the forecaster and observer staff merged their diverse skill sets to craft effective messaging. They were able to track weak layers and provide travel advice with precision not previously seen at the center.

By far the biggest challenge to the NWAC forecasters during this season came at the end of this persistent slab cycle. Forecasters scoured incoming material for data and observations that led to confidence in dropping the Persistent Slab (by then Deep Persistent Slab) messaging from the forecast. While forecasting persistent avalanche problems often presents challenges, they are unique in the quick-changing snowpack of the Pacific Northwest. One challenge is the combination these snowpack characteristics with the user demographics of the region. Even experienced and well-educated backcountry travelers may not have much experience with active persistent slab conditions. In telling users that avalanches may break wider than they expect, it may be extra challenging for travelers in the Northwest to anticipate what that kind of propagation (and resulting avalanches) could actually look like.

Despite the unfortunate string of fatalities, it was a very successful season for NWAC. We are excited to further build our capacities as a team for 2018-19. We will continue to grow field-based forecasting components and more specific regional coverage along with the well-established avalanche weather forecasting side of the center.

—Josh Hirshberg

Northwest: A group of four snowmobilers triggered a persistent slab avalanche and were caught and carried on a slope locally known as "The Funnel" for the terrain trap in the runout. Placement of the ski pole in the picture shows were one of the two snowmobile victims were recovered. *Photo Dallas Glass on 3/4/18.*

Utah: Trent Meisenheimer and Mark White investigate a remotely triggered avalanche that caught and nearly killed a skier. Drone footage is really helpful in providing a unique view of avalanches.
Still from video by Peter Vintoniv

Utah Avalanche Center

Below average snowfall

All regions of Utah had a slow start to a meager season for snowfall. A handful of storms in the fall sandwiched between extended periods of high pressure created a weak, shallow, and completely faceted snowpack. A 2,000 foot-wide avalanche in upper Little Cottonwood Canyon in mid-November gave us a clue of what was to come.

In many places, an ice crust formed around Thanksgiving from warm temperatures and rain. Subsequent storms deposited a little more snow which became another layer of facets on top of the Thanksgiving crust. It'd be easy to focus on this crust/facet combo but it wasn't the only player. Numerous persistent weak layers plagued the snowpack and caused avalanches. Further complicating the snowpack was rain that fell in nearly every month in at least someplace in Utah. Every storm predictably caused avalanches and there were many close calls. Across the state, **39 people reported being caught in avalanches** and eight were injured.

A series of December soaking rain storms up to 10,000 feet combined with above average temperatures to bring short-term instabilities but also to help heal the snowpack. With colder weather and a few more storms, we were finally able to confidently venture in avalanche terrain and had some of the best days of the season.

The overall pattern was a north-south gradient of snowfall. The Logan area ended the season with a near normal snowpack in terms of water content while southern Utah was extremely dry. According to UDOT Forecasters, the Alta Guard Station recorded 288" with 30.31" water, the second time

Colorado: Triggered slides in Maroon Bowl, 4-8-18. The large crowns on looker's left (blue arrow) were intentionally triggered by Aspen Highlands ski patrol on the morning of April 8. The ones on looker's right (red arrow) were triggered by skiers ascending the slope that afternoon, resulting in a fatality. *Photo Art Burrows*

Colorado: Deep crowns from natural avalanches on the east face of Garrett's Peak, East Snowmass Creek. The top of ski area lift is visible in the foreground. Large natural avalanches breaking to the ground occurred every day for over a week in portions of the Central Mountains. *Photo Art Burrows*

in 74 years Alta achieved less than 300", and the **second lowest snowfall on record** (2014-15 was 274"), and third driest (1976-77 had 23.7" water and 2014-15 had 27").

By the time we closed our doors, **we had issued 1,002 avalanche forecasts for eight zones**. The advisories were viewed 424,000 times on our website. Our staff logged 430 field days, 43 field days per person. The split between non-motorized and motorized field days was about 60/40.

No fatalities

Our biggest challenge was communicating the nature of the snowpack. The theme from the previous winter had basically been "ski it if it's white." Following a reasonably stable winter, it was tough sounding like a broken record continually discussing facets and weak snow. Despite these dangerous conditions, Utah ended its second consecutive season with no avalanche fatalities. There were no fatalities the previous winter which was the first time since 1990/1991. This was the third season in a row with no snowmobile fatalities.

No doubt a lot of luck is in involved. The most encouraging point is that the running average of fatalities per year has been on a slow decline. This decline has been occurring despite explosive growth in numbers of people in the backcountry. While we were glad no one died in Utah, our celebration was tempered because two Utah residents died in avalanches out of state.

Staffing

The Utah Avalanche Center is run by an amazing team, many of whom have been working here for decades. The most notable change was Paul Diegel's retirement as Executive Director. Chad Brackelsberg became the new Executive Director in July 2017. Chad brings more than 20 years of corporate experience in technology consulting and program/project management to the UAC with over eight years of involvement with the UAC. Paul remains on staff part-time leading the new Avalanche Education eLearning Program.

Our staff includes a mix of Forest Service and nonprofit employees which includes Chad Brackelsberg, Paul Diegel, Greg Gagne, Craig Gordan, Drew Hardesty, Brett Kobernik, Evelyn Lees, Trent Meisenheimer, Paige Pagnucco, Mark Staples, Bo Torrey, Eric Trenbeath, and Toby Weed.

We also have an incredibly strong Board of Directors. They are well organized, passionate about our mission, active in our organization, and bring a diverse array of talents and knowledge. This spring we doubled our board by adding six new members.

Other highlights

The UAC produced the "**To Hell in a Heartbeat**" video, a powerful re-creation of an avalanche rescue which has been **viewed over 2.3 million times.**

We taught 133 classes to 5,345 people. Most of these were Know Before You Go presentations; however, 31 of them were more in-depth, field-based classes. These introductory classes are a great entry level opportunity and a springboard for Level I and II classes from other providers.

With help from RadioWest producer Benjamin Bombard, we started a podcast. Drew Hardesty hosted it and recorded eight episodes with over 10,000 downloads. We look forward to exploring more topics with this great medium.

Instagram was the dominant social media communication tool again this year. Our Instagram following grew by 40% to 31,057. We hosted our first Instagram Live Chat session. We had 363 postings, including 93 videos which received 949,827 views. The top video posted on January 9, 2018 received 131,000 views.

USAW packed 900 people into the Snowbird Cliff Lodge Ballroom for a 50% increase in USAW attendees from prior years. Also, we included a motorized specific session which we hope to expand in coming years.

The UAC purchased a DJI Inspire 2 drone in August to allow us to continue to improve on the avalanche reporting and education videos that we create.

Lastly, Brett Kobernik finally debuted his fully custom built "Goliath, the Powder Pagan" snowbike. There is nothing like it in the world. Brett built it himself using a huge 950 KTM motor and a modified 174" track. There are rumors it may get a turbo next winter.

Our sponsors, supporters, and partners are too numerous to thank individually. For this publication, we'd like to express our appreciation to all the avalanche professionals and other passionate folks who help us do our job all winter. Additionally, we need to thank all the athletes, ski areas, and wintersports companies.

—UAC Staff, compiled by Mark Staples

Colorado Avalanche Information Center

The 2017-18 avalanche season in Colorado was characterized by a stark north-south gradient in total snowfall, and warm, wet storms punctuating prolonged dry spells. In portions of the Central and Southern Mountains, it was **one of the driest winters in the last 40 years**. Our Northern Mountains fared better, with some areas quietly sneaking in a decent season with near or even slightly above median annual snowfall. Rain as high as 12,000 feet and several dust events made many us of wonder how winter might look in the future.

There were **approximately 2200 avalanches reported** to the Colorado Avalanche Information Center (CAIC). We documented 35 incidents, with 45 people caught and three killed —less than the 10-year mean of six fatalities per season. The numbers are likely affected by a shortened snowpack season, particularly in our Southern Mountains, that had long stretches with little avalanche hazard due to poor snow coverage.

An early October storm dropped enough snow at higher elevations to persist through a pronounced fall/early winter drought. A thick foundation of depth hoar developed across much of

Kachina Peaks: Fremont, Agassiz and Humphreys Peak from left to right. March 22, 2018. Northern slopes above 10,000 ft had sufficient coverage but a dry and hot spring quickly reduced the snowpack. *Photo Troy Marino*

the state. This layer plagued us for the remainder of the season. We received four "storms" during this drought period with very little snow accumulating prior to Thanksgiving. Each of these storms was followed by extended dry periods of at least a week. Our first close call occurred right after one of these modest loading events on November 18, when a snowboarder near Aspen was caught, carried, and partially buried. Fortunately, he walked away with no major injuries.

The longest period without significant snowfall was from November 18 to just before Christmas. During this five-week dry spell, the snowpack around the state dropped to less than 75% of long-term median, with some areas in the Central and Southern Mountains in the single digits. A "Christmas storm" finally brought snow we could measure in feet. Our snowpack did not handle this test well, and we saw our first, and in hindsight, most widespread avalanche cycle of the season. This pattern - mid to late-month storms interrupting dry periods and leading to avalanche cycles - continued into April. The avalanches in each cycle failed on the facet layer that developed during the early-season drought

The first fatality of the season occurred right after the mid-January storm in the San Juan Mountains near Silverton. Two backcountry skiers were caught and partially buried after venturing into terrain they planned to avoid. One did not survive. This hit the local community hard, as the victim grew up in the area.

February was the snowiest month of the season for the entire state, accounting for a large percentage of snowfall for the entire season. In some locations in the Southern Mountains, February snowfall amounted to around half of the season's snowfall. Not surprisingly, we also had a lot of associated avalanche activity, and a little over one third of all avalanche incidents occurred during this one month. The month's incidents include a solo skier near Berthoud Pass who was caught, carried, and sustained injuries, and a skier near Vail Pass who was partially buried and suffered serious injuries requiring hospitalization.

Mid-February storms produced a remarkably sustained cycle of large and very large avalanches, with **D2.5 or larger slides nearly every day** for over a week in some locations. The cycle left many professionals searching their memories to recall such a long-lived cycle of avalanches breaking to the ground with very small loads or even just a minor uptick in wind transport. It also had lots of us of tip-toeing around the backcountry.

March was mostly warm and dry. Warm, springtime temperatures brought a few days of small wet avalanches throughout March, but we didn't get a pronounced Wet Slab avalanche cycle until later in the season. Storms in the latter half of the month brought rain to 11,000 ft. We had several close calls during the month, but entered April with hopes of finishing the season with only one tragic avalanche fatality.

It was not to be. One of the season's largest storms arrived on April 6, delivering ample heavy, wet snow over the next three days. Snow-water-equivalent was up to 4 inches of water with 2 to 3 feet of snow in the favored locations. We observed rain close to 12,000 feet at the tail end of the storm. This was an unusual event, and two fatalities occurred in the three-day period right after the storm lifted. On closing day for Aspen Highlands (April 8), a member of the local Search and Rescue group was caught, carried, and killed in the backcountry adjacent to the ski area. An avalanche warning was in effect at the time of accident. On April 10, snowmobilers near Breckenridge triggered an avalanche that broke on the early-season, basal facets. The victim was fully buried and killed. He was wearing a beacon, but it was not turned on. It was sobering to enter the final stretches of the season with two more tragic accidents, each of which has take-home lessons that are too familiar. A number of Wet Slab avalanches followed later in April and into May.

On the education front, the CAIC and Friends of CAIC continued the Know Before You Go program statewide. Combined with our other educational programs, CAIC staff and trained instructors across the state conducted around 150 education events and reached approximately 6300 students. We look forward to improving and expanding these programs for next season.

—Brian Lazar

Kachina Peaks Information Center

The 2017-18 season in Arizona was the **fifth driest winter in over 100 years** of meteorological record keeping with 42% of average precip (NWS, Flagstaff). It was also the most snow deficient winter since Kachina Peak Avalanche Center's inception in 2005. Our 10,800 foot (3292 m) study site received 35% of average snowfall, totaling 95 inches (241 cm) between October 1 and May1, 2018.

The season didn't really start until January 10th with the first significant snowstorm of 14 inches (35.5 cm) at 10,800 feet. This storm seemed anomalous in the otherwise iron clad high pressure lockdown, which, like most of the western USA, was deflecting precipitation to north. The drought then continued for another month. On February 10 pattern change brought us 15-18 inches (38-46 cm) of new between the 10th and 15th. By the end of February, 45 inches (114 cm) of snow had fallen, making it our wettest month of the season.

At the beginning of March our settled snow base at 10,800 feet hovered around 39 inches (99 cm) for a couple of weeks, representing the zenith depth for the winter. Storms then tapered off throughout March with the Vernal Equinox marking a literal and symbolic transition to spring-like conditions. During April, windy and dry weather dominated, accelerating the melt-off and reminding us of the potential catastrophic fire season to come. No natural or significant human triggered avalanches were reported during the entire winter season. Basically our winter was a write off, but our hopes are high for more snow next winter – "Feeling better all the time - it cannot get no worse."

Avalanche education

As usual, we participated in the Flagstaff Festival of Science, Science in the Park event, running our popular avalanche simulator. We ran several free "Introduction to Avalanches" presentations at local sports shops and community centers. Of five recreational level 1, and two level 2 courses

planned, only one level 1 course ran. Although enrollment numbers were healthy, backcountry snow coverage never became sufficient to safely run productive courses. The one level 1 course we conducted took place Feb. 27- Mar. 3, combining Northern Arizona University students with participants from the general public, forming a class of 10 students

Public bulletins and website activity

Twelve weekly snowpack summaries were published on our website, starting on December 4 and ending on April 17. Some interesting trends surfaced from our analysis of website usage data. We had low numbers, including the lowest user count for kachinapeaks.org since we started using Google Analytics in 2011. However, when looking only at Arizona and Flagstaff and user totals for the snowpack summary only, seasons 12/13, 13/14, and 14/15, each had lower numbers than this season. So while we had a low overall user count, it seems that for AZ and Flagstaff, we have developed a base of users who are still interested in the snowpack summary despite the drought. This is encouraging from a sustainability perspective. It shows continuing local support, despite the obvious high variability in our winter precipitation.

Winter backcountry permits

Since 1996, Coconino National Forest has administrated a free season-long winter backcountry permit for visitors of Kachina Peaks Wilderness. This is primarily an effort to promote avalanche safety awareness, but is also useful in tracking winter recreational trends. Considering the lean snow coverage during the winter, **a surprising high number of winter backcountry permits were issued, totaling 631**. Thirteen Coconino National Forest volunteers who dedicated 210 hours at AZ Snowbowl resort on Saturday and Sunday mornings issued 55% of these. The remaining 45% were issued to visitors from either the Flagstaff Ranger District or the Forest Supervisor's offices.

—David Lovejoy (KPAC)
Troy Marino (KPAC)
Patrick McGervey (Coconino National Forest)

Eastern Sierra Avalanche Center

The 2017/18 season marks Eastern Sierra Avalanche Center's (ESAC) twelfth season serving the backcountry community and saw a number of seasonal firsts. 2017/18 was our **first season as a Type-1 Center issuing daily avalanche forecasts,** a significant milestone in ESAC's evolution. This was the first full season with three forecasters on staff, which is critical for scheduling and operational flexibility as a Type-1 Center. This season also saw the **first time the Center issued an Extreme rating;** the associated avalanche cycle was the largest of the season.

The season started out with much hopeful anticipation among skiers and riders for a normal, or possibly better, season given the past two seasons of near normal to well above normal precipitation. As the first major storm rolled off the Pacific in November, there seemed to be some support for their optimism. However, this wasn't a harbinger of things to come. The season turned unexpectedly dry from December through February, with the clear skies only interrupted by the occasional "**inside slider**" storm from the Pacific Northwest riding down the backside of the ever-present high-pressure ridge parked off the Pacific coast of California. The "inside sliders" brought some welcomed light snowfalls and bursts of unseasonable cold temperatures throughout the region. This combination helped to form a shallow snowpack with widely variable bridging over a persistent weak layer of facets in the mid-pack in deeper locations or well–developed depth hoar in shallow pockets for a good part of the season.

INSIDE SLIDER: A shortwave trough moving southward along the eastern side of a ridge of high pressure usually responsible for cool breezy and sometimes showery weather.
—Golden Gate Weather Services

The persistent problem lingered well into February. Never quite enough snow to completely bridge over the weakness with confidence while just enough snow to perpetuate the risk. Then the second coming of the "**Miracle March**" saved the season and turned around a rather shallow snow year. March came in like a lion, then relaxed a bit mid-month before regaining momentum for a strong snowy finish. This brought the snowpack from 25% to 35% of normal to 80% to 85% of normal for central Sierra, which was welcomed relief in terms of water and snow. However, with the much-needed snows of March came tragedy, two people in Kirkwood were buried by a roof avalanche and killed during the first heavy snowfalls of March. The first week of April saw a quick transition from a late winter snowpack to spring conditions as a unusual late season Atmospheric River enhanced storm plowed into the Sierra with heavy rain up to ~12,000' and initiating the second largest avalanche cycle of the season. The remainder of the season closed out with intermittent spring storms bringing some late season powder over a firm spring base. As the quick moving storms moved off to the east, temperatures generally rebounded as spring reasserted control with seasonable temperatures and clear skies. Looking back, it's possible a couple of mid and long-term climate conditions combined to be the dominant players during most of the season. January through February saw a strong Madden-Julian Oscillation (MJO), which tends to limit convective development in the western Pacific and form a stubborn high-pressure cell along the Pacific coast. A modest La Niña may have reinforced the trend by nudging the jet stream further north, steering storms into the Pacific Northwest, which then slid into the lower Great Basin before ejecting to the east.

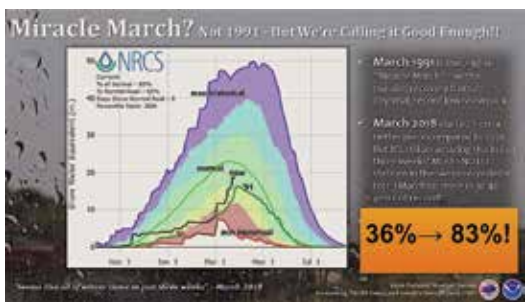
The 2017-2018 season was challenging for the staff at Eastern Sierra Avalanche Center (ESAC). With drought conditions in the west, the eastern Sierra saw faceting of the mid-pack and depth hoar development in the lower snowpack, producing an uncharacteristically weak snowpack for the Sierra. "Low likelihood/high consequence" and "failure in tests vs. slope-wide failure" was the concern and dominated the discussion among forecasters. This concern lingered through March until it was well buried and bridged and was one of the biggest forecasting challenges of the season.

Another forecasting challenge comes with a new name, **Snow Drought**, but not unknown as climate change takes its toll on the western US snowpack. Snow drought has been come a more common phenomena in recent years with either limited snowfall and/or high snowlines. The ESAC forecast region is defined by the wilderness areas (Ansel Adams, John Muir, Owens River Headwaters Wilderness, Hoover Wilderness) and national parks that line the western edge of Long Valley; Yosemite NP, to the north, and Sequoia-Kings Canyon NP, to the south, form a nearly continuous chain of undeveloped land along the western boundaries of the forecast region. Additionally, the eastern Sierra lacks the extensive mining typically found in the western mountains. The combination of wilderness areas, national parks and the lack of extensive mining and the associated development has helped to preserve the natural character of the landscape along with minimal development but restricts access to a limited number of road accessible trailheads. The trailheads are often at or below the snowline, which requires longer approaches to the snowline and further still for adequate snow coverage. The result is increased travel times with diminishing returns. Obtaining observations requires greater time investment with a corresponding drop in observations in general, from the public and the Observer Network, throughout the forecast region.

The limited observations for an area that covers well over 1,000 square miles and nearly 70 linear miles in length increases the challenge and adds an additional element of uncertainty. **The dearth of information was one of the biggest challenges of the season**, along with keeping people motivated to ski and post while out in the backcountry. This was evident during the snows in March when avalanche conditions spiked but observations submitted remained relatively low. For most of this season, only two trailheads offered snow at the trailhead, which tended to funnel traffic to those areas while leaving other regions within the forecast zone with very limited visitation and observations. As the trend toward irregular seasonal snowfalls from year to year and rising snowlines, the challenge will only increase.

—Doug Lewis

February drought coverage in the southern area.
Photo Clancy Nelson



NWS Miracle March Graphic.
National Weather Service—Reno

Sierra Avalanche Center

Near Drought Conditions, Deep Slabs, and a Miracle March

The operations side of the Sierra Avalanche Center returned unchanged this year with Director/Lead Forecaster Brandon Schwartz and Avalanche Forecasters Andy Anderson and Steve Reynaud. Travis Feist and David Reichel continued as professional field observers for the southern portion of the forecast area.

Winter 2017-2018 started with much anticipation as an early season storm in October brought high elevation snow. After a dry spell, most of this snow melted and left a layer of poorly developed facets on high elevation NW-N-NE aspects. A large Atmospheric River (AR) storm moved into our area with up to 8" of rain up to 9000' and 3-4' of new snow at the higher elevations. During this storm on November 16, a group of four experienced locals was involved in our first avalanche incident of the season when they triggered a deep slab avalanche on the basal facets on Hourglass Bowl in the Mt. Rose area. Two people were partially buried and injured, but the group was able to self-rescue.

After this storm, winter mainly turned off until the 3rd week of February. December, January, and most of February were some of the driest on record with a total of 95" of snowfall. With limited snow at higher elevations, snow recreation was limited to three main higher elevation locations: Mt. Rose, Carson Pass, and Castle Peak areas. Most of our usable backcountry terrain is located between 7000-9000' with many popular trailheads below 7000'. During this time, snow line was around 7500' with "mostly" skiable conditions above 8000' in the northern part of the forecast area and above 8500' in the southern part of the forecast area. Stoke was low around the area as many folks ditched their skis for mountain bikes.

Finally, by mid to late February colder air and storms started to impact our region. Then **one of the snowiest Marches on record happened**, almost doubling the amount of snow received for the rest of the winter. With a shallow snowpack, rapid loading in March brought three deep slab avalanche cycles. A layer of near-surface facets at higher elevations that formed on or near the ground below 8000' developed during the 3rd week of February. The first deep slab cycle occurred in early March when **a large party remotely triggered a substantial D3 slide** that remarkably went around and missed the group. Another larger and widespread deep slab cycle occurred in late March on the same layer when a strong AR storm with 8-10" of rain up to 9000' impacted our region. Large D3-D4 avalanches with dry and wet slab characteristics scarred the terrain throughout the forecast region. A smaller and unique deep slab cycle occurred in the Mt. Rose area on a buried persistent graupel layer in the middle of March. This layer of graupel was deposited on top of a melt freeze crust and was responsible for an avalanche cycle that lasted eight days. Many natural and human triggered avalanches occurred with a group remotely triggering a deep slab avalanche from a ridge that failed on this graupel layer.

April brought more high elevation rain and then a return to warmer spring-like temperatures. Overall precipitation was close to average for the season, but with warmer temperatures and higher snow levels, total snowfall was in the 70-80% range. Many challenges existed throughout the winter including managing multiple deep slab avalanche cycles. With the winter being either on or off, warning the public that our shallow snowpack could produce large avalanches was another hurdle we encountered when it finally starting snowing.

We issued **142 daily avalanche advisories** from December 1 through April 22. The number of advisories issued for each danger level was: 46 Low, 65 Moderate, 26 Considerable, 5 High, and 0 Extreme. Four avalanche incidents were reported this year, involving eight people. Out of these eight people, two were buried and killed in a roof avalanche, three people were partially buried, and two were injured. The roof avalanche occurred near the Kirkwood Ski Resort when a mother and her seven-year-old son were returning from skiing at the ski resort. As they took a shortcut through the woods back to their condo complex, the snow from a roof released and buried them under three feet of snow.

The Sierra Avalanche Center functions as a partnership between the Tahoe National Forest and a volunteer Board of Directors with 501(c)(3) non-profit organization status. The SAC has had some major personnel changes this season. Executive director Don Triplat has retired after serving for a decade as ED, previous board president, and as a board member. We thank Don for all his hard work and wish him luck on his new ventures. Don is replaced by Mark O'Geen, who grew up in the Central Sierra foothills and comes with avalanche experience from ski patrol, avalanche education, and as an avalanche specialist with WDOT. President Holly Yocum has also passed the torch on to new President Mark Bunge. Mark has been an

Tahoe Sierra: Deep slab snowbike-triggered avalanche on buried facet layer. Lost Lake, Carson Pass on March 9, 2018. *Photo: Lenny Decker*

Tahoe Sierra: Remotely triggered deep slab avalanche from over 500' away. Forecaster was digging a snowpit on a 27-degree slope when a whump occurred and cracks propagated to steeper terrain where this avalanche occurred. Shooting cracks were over 1000'. Johnson Canyon, Donner Summit area March 4, 2018.
Photo Steve Reynaud

active board member and has a background in political and market research. Holly has served as board president for three years and will continue as vice president.

The SAC board also created a new staff position of Education Coordinator. Professional observer Travis Feist takes on this position that focuses on our backcountry and snowmobile avalanche awareness and outreach programs. Through continued funding from a CA OHV grant, SAC's snowmobile avalanche education program continues to run snowmobile Level 1 avalanche courses. The non-profit SAC and the Tahoe National Forest continue to work together to provide funding and operational support for the avalanche center. With their support, we continue to be an expanding avalanche center providing avalanche forecasting and educational outreach to our central Sierra Nevada community.

—*Steve Reynaud-Avalanche Forecaster*

Mount Shasta Avalanche Center

A painful statistic: December, for Mount Shasta, was the **second driest December in the past 107 years.** Indeed depressing, but we didn't let it get us down. The US Forest Service Mount Shasta Avalanche Center (MSAC) finished its 20th season of operation this year and we're stoked on that! Despite many zones in our advisory area struggling to form a snowpack this season, the mountain itself was our snowmaker. Upper elevation snowpack on Mount Shasta slowly grew, and frequent storms in March and April ended the season on a high note. The winter was characterized by well below average precipitation and unseasonably warm temperatures. During the wet season (October-April) Mount Shasta City received 17.17 inches of water which is 47% of the historic average of 36.27 inches. April snow surveys also revealed that the Mount Shasta area snowpack was less than half of historic averages.

Despite the low snow winter, the backcountry community in Mount Shasta stayed positive and took advantage when conditions were good. Overall, natural and human triggered avalanches were a rare occurrence and LOW avalanche danger was issued in 67% of this season's avalanche advisories. The MSAC is happy to report that no one was caught, injured, or killed in an avalanche in our advisory area during the 2017-18 winter. There were three documented reports of human triggered avalanches up to destructive size 1. Only **23 natural avalanches were documented** by MSAC staff, two of which were classified as destructive size 2, the rest were destructive size 1. We observed three types of avalanches: wind slab, loose wet, and storm slab. Shallow snowpack hazards, falling rime ice, and slide for life conditions posed greater hazards for backcountry travelers than avalanches most days this season.

For the 2nd season in a row, the MSAC had 3 full-time employees. Nick Meyers returned for his 9th season as the Director and Lead Forecaster, Andrew Kiefer worked his 2nd season as an Avalanche Forecaster, and Aaron Beverly worked his 2nd season as a Professional Observer. We couldn't be happier as each player brings something unique and different to the table, a recipe for a fantastic team. Nick rolls with 16 years of solid local knowledge and professional experience on Mt Shasta as a USFS climbing ranger. Nick is also an essential and important bridge between the community, the Forest Service, and the Friends group. Andrew, the youngest of the bunch, brings spot-on critical thinking skills and has functioned as a much needed fine-tooth comb for the center. Aaron, the tribal elder, bangs out some really great website magic that only he understands. Nick and Andrew bow down on a daily basis to Aaron's computer skills. Aaron's solid field observations and high integrity round him out as a critical third of the team.

Avalanche education, outreach events, and several projects kept us busy as well throughout the season. MSAC staff delivered **18 avalanche presentations reaching 527 people** in California and Southern Oregon. Free Know Before You Go (KBYG) avalanche awareness and companion rescue clinics were offered the first Friday and Saturday of each month: December, January, February, and March. Similar presentations were given in Ashland and Medford (Southern Oregon). In addition, KBYG avalanche awareness presentations were given to local school groups. Avalanche trainings were also provided to USFS employees for snow survey. Our 6th annual **Snowmobile Avalanche Workshop attracted 43 rider**s from California and Oregon. We were fortunate to have packed houses for our movie night and annual Snowball bash, the biggest fundraiser of the year. For the Shasta Ascension Backcountry Race on the mountain, 67 participants competed, a record number. Other happenings include a complete website makeover of www.shastaavalanche.org with several updates and new features added as well as the launching of our snowmobile ambassador program. Lastly, the MSAC conducted an operations review with the USFS National Avalanche Center.

The Friends of the Mount Shasta Avalanche Center (FMSAC) is our nonprofit partner that formed in 2002, and is an essential component of

Mt. Shasta: A gorgeous sky and contour line out along a lava flow, east side of the forecast area. *Photo Nick Meyers*

Mt. Shasta: In about 10 minutes, one can ride from 7 to 10,000 feet on Mount Shasta. An easy afternoon ride for a quick ski lap, observation, or picnic. *Photo Nick Meyers*

the Avalanche Center. The Friends fund and operate the MSAC website and all five of our remote weather stations, trainings, and other various needs of the center. They also organize all fundraising events, and help with the education and outreach components of the avalanche center. FMSAC is a volunteer group with one paid position, the Executive Director, Justi Hansen. The group represents the soul of adventure and passion for backcountry mountain recreation in the greater Mount Shasta area. We extend a huge thank you for all of their effort and support this season.

Season after season, a nagging, deeply seated insecurity lurks in our minds: accurately forecasting for wind slabs and further, the likelihood for triggering. **Why is it we are seeing so few wind slab avalanches, or often times avalanches in general, even though we continue to see large storm events with several inches of water and feet of snow with high winds?** What are additional ways beyond those that already exist to best test and forecast for the wind slab problem? The wind slab avalanche problem is the premier problem on Mount Shasta, a 14,179 foot mountain rising thousands of feet above the surrounding terrain of Northern California. Crown lines and debris piles dance through our dreams, yet so many times we've woken to field days with not an avalanche in sight. Large, seemingly identical storms produce opposite results. Wind slabs, or lack thereof, leave us searching for how we can better forecast and test for them. The MSAC crew has some ideas for next year. We're starting with some simple data recording with hopes that it will highlight patterns that perhaps we are missing in the day to day. Maybe this will lead to further questions to help turn the dial in on this illusive avalanche problem.

As always, we want to thank the fantastic tribe of folks that come together and contribute to keeping the gears greased for the MSAC. Next season we will launch all of our same offerings and modes of operation. We just hope to get more snow, because just like money, it's never enough!

—Nick Meyers

Mount Washington Avalanche Center

Temperature swings and diversity in precipitation types brought varied conditions and unique avalanches to Mount Washington for the 2017-18 season. The summit weather observatory recorded **344" of snowfall from October to May**. Bouts of snowy, winter conditions alternated with strong warming events. Arguably the best corn snow conditions of the year occurred mid-winter, while spring saw significant avalanche activity. Through these varied situation, our avalanche center worked to expand public outreach efforts, keeping us quite busy.

Frank Carus completed a second season as Director, and Helon Hoffer and Ryan Matz remained on staff. A fourth position remained open and will be filled for the 2018-19 season. Our staffing shortage was eased by valuable temporary workers Jeff Fongemie and Amanda Tulip. Lily Carus, our avalanche rescue dog, continues to have a stronger positive impact on our social media following than all other efforts combined.

December 1st brought the first human triggered avalanche of the season, albeit in a minimal early season snowpack. Our first five-scale avalanche advisory was issued on December 12th and a High rating appeared the following day, the first of 12 High ratings issued throughout the winter. The snowy theme continued for December, filling in our avalanche paths, producing natural avalanches, and bringing promise of a big snow year.

Early January remained wintry, providing very good days for skiers and riders and by January 11th our seasonal snowfall total was 144". January 11-13 brought 3-4 inches of rain to the mountain as temperatures soared towards 50 degrees F, engendering **a massive wet avalanche in Tuckerman Ravine**, which released at or near the ground for a crown height of up to 20 feet. This avalanche ran only 600 vertical feet, but 1800 feet in length to toe of the debris. A rapid refreeze followed, leaving this crown as a distinct feature in our terrain for much of the season.

A robust crust marked our early January melt/freeze event and dominated our terrain through early February. New snow struggled to bond with this older surface, allowing wind to easily and repeatedly scour most storm snow out of our terrain. Bonding improved slightly by February 8th, when Frank and Helon were able to witness a large hard slab release naturally in an event that we affectionately call a "**bowlalanche.**" This significant snowfall and natural avalanche cycle in early February gave skiers and riders some hope before another melt/freeze brought crampons back to the top of our gear lists. Long sliding falls on the slick refrozen snow became frequent mentions in our advisories. Several such accidents occurred late that month as our "snow" surface became incredibly hard and slick.

March brought repeated storms and finally returned a more dynamic nature to our upper snowpack. Several backcountry travelers were involved in relatively minor avalanche accidents early in the month. This was prior to a **widespread natural avalanche cycle in mid-March** which resulted in numerous alterations to known avalanche paths.

Wintry conditions continued into early April. Seven human triggered avalanches were reported on April 7th, all in relatively thin recent storm snow. One of these caught and carried at least five people of the 40 or more who were simultaneously in a single avalanche path. A few minutes later a small slab of hangfire was triggered above the initial crown and rescue party. Witness reports suggest that the same individual triggered both avalanches. Ultimately, only one skier required evacuation.

In late April, a switch flipped: We issued a High danger rating on April 21st for a strong high elevation storm and issued our last advisory of the season on April 24th, for a total of 134 advisories total. Rain and warming rapidly depleted the

Mount Washington: Wet slab, Tuckerman Ravine: January 12th, 2018. *Photo Joe Klementovich (klementovichphoto.com)*

IS IT TIME TO CHANGE YOUR UNDERWEAR?

Peter Brandon braces against a strong gust while preparing to rappel off Mt. Katahdin's Knife Edge.
BRENT DOSCHER

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snowpack. Combined with unstable conditions earlier in the month, a damper was put on the usual Tuckerman Ravine spring ski scene.

The Mount Washington Avalanche Center is also responsible for SAR in the area we forecast, the east side of Mount Washington, from December 1 through May 31 each year. We responded to a number of relatively minor incidents with the much-valued help of the Mount Washington Volunteer Ski Patrol. Through some combination of coincidence, luck, and hopefully some good decision-making, visitors to our terrain had a relatively safe season.

A number of efforts to expand our connection to the digital world took place over the winter due to attention from the Friends of Tuckerman Ravine. Website changes include the addition of daily snow plot and wind data to our advisory page. We plan to introduce a more significant overhaul to our advisory product for the 2018-19 season.

The White Mountain Avalanche Education Foundation, a nonprofit partner of the avalanche center, expanded **our public outreach efforts by reaching nearly 800 individuals**. Fourteen events included audiences young and old in presentations for youth and school programs, awareness talks, and advanced topic presentations, which should all continue for the upcoming season.

The 2017 Eastern Snow and Avalanche workshop drew a record crowd of almost 200 people.. We'll be kicking off the snow season with ESAW again this year on November 3; hope to see you there!

—Ryan Matz

Chugach National Forest Avalanche Information Center

The Chugach National Forest Avalanche Information Center (CNFAIC) completed its 17th season on May 1st of 2018 and its 10th season issuing danger ratings. Of all the warm and rainy years of the past, last year treated us well. We averaged 57% of our normal snowpack, which sounds dismal, but in fact our saving grace was a relatively cold winter. Most of the snow that fell, fell to sea level and once there, mostly stuck around. As a result, persistent weak layers plagued the Turnagain Pass region and several unusual avalanches were seen, including several near misses. A much too common topic in our weekly stability meetings was, '**when/how/if to go to LOW**' with buried (dormant?) facets…

After narrowly escaping the forecast season without a fatality in our region, sadly in May a snowmachiner lost his life in an avalanche riding on the Blackstone Glacier south of Whittier on the Chugach National Forest. Alaska averages three avalanche deaths per season and the 2017/18 winter tragically saw three. A longtime skier passed away at Hatcher Pass in November and a snowboarder died in the mountains outside of Ketchikan in February.

We had several highlights. In January of 2018, Alaska's Division of Parks and Outdoor Recreation signed a Memorandum of Understanding with the CNFAIC. **This agreement allows us to work with Alaska State Parks in extending public outreach and information sharing to certain State lands susceptible to avalanche accidents.** This season we also worked closely with the National Avalanche Center to improve our daily avalanche advisory product to include avalanche likelihood and size scales. During the early season, the Friends of the CNFAIC Executive Director facilitated 'editor briefings' with local news outlets to build relations and provide resources to help with media product accuracy. Looking forward to next winter, the Friends of the CNFAIC will be installing a ridgetop weather station in the data-sparse region of Lost Lake, on the Seward Ranger District. This will provide weather information and webcam images to an area where avalanche terrain and significant snowmachine use overlap.

In our ongoing goal to fulfill a core component of the avalanche center's mission, the CNFAIC had another successful season of free avalanche outreach to the motorized and non-motorized communities. We continued our "**Fireside Chat**" series with topics focused on **Lessons Learned. Presentations** delved into discussions of the snowpack and events leading up to accidents and close calls that had recently occurred. These were a great way to review formation of weak layers, highlight how winters can be dramatically different, discuss the five 'Gets' and look at mistakes we can all make in avalanche terrain.

This year **our staff introduced new worker safety protocols**. We committed to practicing companion rescue with field partners several times over the winter. This created an environment to keep rescue skills sharp and for volunteers to get more practice under pressure. We also adopted a formal field day morning briefing and debriefing process (spearheaded by Heather Thamm). The Pre-Trip form prompts the team to discuss the avalanche forecast, weather, pertinent observations, route, and objectives for the day. The Post-Trip form includes a series of questions to examine exposure in avalanche terrain and discuss any lesson learned. Overall, this process helped our communication with field partners, ensured understanding of avalanche hazards and the plan for managing those hazards. The debrief also gave us space to reflect on our day and identify any errors we made or unnecessary exposure.

The CNFAIC runs an internship program and we had an opportunity to take on two interns, husband and wife team Jessie Haffener and Sam Galoob. These two eagerly jumped in to gain operational experience in a backcountry forecasting program. Originally from Oklahoma, they chose to leave their Alaska jobs in the oil industry to pursue their outdoor passions and career aspirations. Their internship project was titled, "Considerations for Optimal Management of Periphery Zones in Southcentral Alaska". They compiled statistics, anecdotal evidence, and communicated with avalanche centers across the Western US. Our center has been struggling with ways to use our resources as wisely as possible with respect to 'periphery zones.' Their research proved what we suspected – that broadening our advisory zone and expanding observation regions is the direction to head.

As with many centers, our non-profit arm, the Friends of the CNFAIC, is critical to our operation. They provide over half our total annual budget and continue to grow; this coming year will be their third with a funded Executive Director. They also **hosted the first motorized-specific fundraiser to a sold out crowd in November of 2017!** Furthermore, the Friends group has increased funding to the Forest Service through a Challenge Cost-Share agreement, allowing all three staff members to work a full six months. The center is in an exciting place as we move forward in conjunction with all staff returning, Heather Thamm, Aleph Johnston-Bloom, and myself. Look for some changes this winter and possibly a phone call or email as we seek advice from the greater avalanche community!

—Wendy Wagner

Alaska Avalanche Information Center

The five regional avalanche centers that currently make up the AAIC provided **565 avalanche forecasts**, received hundreds of observations, taught 62 education outreach programs, and contracted avalanche safety services for companies and organizations that reached across Alaska from Haines to Fairbanks to Valdez during the 2017-18 season.

Partnerships with cities, boroughs, and municipalities continue to grow and strengthen along with support from local newspapers, radio, snow-

Chugach: Local skier Mike Ausman captures a large D3 deep slab avalanche triggered remotely from below by two skiers. Skiers narrowly missed being caught in the runout by skinning/running out of the path as the avalanche barreled down on them. *Photo Mike Ausman*

machine clubs, universities, and the Alaska Department of Public Safety.

During this season the AAIC education team taught **a total of 47 community awareness and general backcountry preparedness courses** that ranged from 30 minutes to four-hours, nine AIARE Level 1 & 2 courses, and six one-day sled specific workshops. The community courses included school children from 1st grade through high school, as well as community organizations and groups. The Backcountry Safety program Live to Ride Another Day was sponsored by the Alaska Department of Public Safety, Division Alaska State Troopers, and reached more than 6,500 individuals in communities across the state from Anchorage to Ketchikan to Fairbanks to Valdez.

The AAIC once again hosted an annual Snow Safety Summit in Anchorage on November 2. This year's agenda focused on communication among Snow Safety Practitioners, government agencies, and the media. This event was followed by the Southcentral Alaska Avalanche Workshop on Friday and community outreach with the Community Snowfest on Saturday at Alaska Pacific University. The 2018 Summit, sponsored by Conoco Phillips and Alyeska Pipeline Service Company, is set for Thursday, November 8, 2018, at the BP Energy Center in Anchorage. More details available at https://alaskasnow.org.

Alaska reported three avalanche fatalities during the 2017-18 season. A skier in Hatcher Pass (November,) a snowmachiner in Ketchikan (February,) and a snowmachiner in Blackstone Glacier near Whittier (May.) The AAIC team continues to raise awareness, share information and training opportunities, and collaborate with other organizations and agencies in an effort to reduce the number of unintentional injuries and death by avalanches in Alaska.

Total of all centers

- Published forecasts: **565**
- Website Visits: **88,258**
- Education programs taught: **62**
- Served approximately **7,000 individuals** with training this season

From the five current AAIC community avalanche centers:

Cordova Avalanche Center:

Cordova's winter began with a warm and wet October, bringing some snow to the upper mountains but mostly rain. An unusually dry November left a shallow snowpack. December and January had a handful of big storms with strong wind, heavy precipitation, and warm temperatures.

The town received three feet of water in two months. These storms caused several avalanches, but the lack of snow in lower elevations kept debris from traveling far. By the end of January enough snow existed in lower elevations to allow the local ski area to finally open. February brought relatively normal weather, though the snowpack remained below normal. From mid-March through most of April Cordova experienced a prolonged dry period.

Strong northerly outflow winds and low humidity caused much snow to sublimate. Near the end of April into May, a series of storms brought 14 inches of water in 14 days, with the freezing line fluctuating between sea level and the local peaks. This left several feet of new snow in the upper mountains, and caused several medium to large avalanches. Spring shed began soon after as temperatures increased. **Overall, this winter had near normal precipitation, warm temperatures, and a shallow snowpack.** No avalanche accidents were reported in the Cordova area, and no activity reached the highway. The CAC published 23 Forecasts and provided backcountry safety outreach in local schools.

—Hoots Witsoe

Eastern Alaska Range Avalanche Center:

The Eastern Alaska Range Avalanche Center had another successful season of bringing avalanche awareness to the Interior of Alaska. Our goals of education, observations and weather forecasting were all met. We offered various education opportunities, but **our highlight was hosting 40 snowmachiners in an 8-hour workshop** held in January. We had seven instructors volunteer to serve this group.

Eastern Alaska: Digging a pit during a Level 1 training. *Photo Peter Winsor*

In addition, we offered a variety of other courses, including a Level 1 AIARE course that started in Fairbanks and then wrapped up with field work at the Black Rapids Lodge. We reached further into the sledding community with a presence at Arctic Man and SnowCross 2.0. Arctic Man had great audience participation with more than 150 attendants due to engaging activities that focused on interactive backcountry travel workshops.

Finally, we have made progress towards getting our weather station installed for next season but still have work to do to finalize the process.

Our web observations were stagnant this season in terms of post quantity. This will be a priority next year assisted with new weather data.

—Mark Oldmixon

Haines Avalanche Information Center:

This season was a tough one for the snow-lovers in Haines. Our first skier-triggered slide [SS-AR-D2-R3-S] was reported October 28th: a scary close call and an ominous start to the season. We're ending the season with another scary close call, reported from April 27th [HS-AC-D3-R4-O].

We started with an unusually thin, weak snowpack, with fully developed depth hoar by November. We waited and waited for those classic maritime dumps, and they pretty much never came.

In mid-January we got our first big storm cycle, but it came in way too warm: heavy rain up to 7,000 ft. (once quite unusual, this is becoming a familiar pattern over the last four years). That storm put down a killer ice layer that would, predictably, become our primary avalanche problem of the year. We got a few inches of cold fluff on top, followed by arctic cold weather, causing rapid near-surface faceting and crust-faceting. It all came to a head in early March, when those old NSFs were buried under a 60cm slab, and stressed right up to the tipping point.

The snowpack was on a hair trigger. Skier-triggered slides were everywhere, with 28 degrees being the threshold slope angle. No burials were reported, probably because the danger signs were unavoidable. We were also sounding the alarm through our website and social media accounts. Public observations were pouring in.

It took another two weeks before we got a "reset." This was a large avalanche cycle caused by 90+ cm of new snow and another heavy rain event. We upped the danger to Extreme, and it verified pretty well after the fact.

In the end, the lack of heavy snowfalls combined with major mid-winter melt events caused a near-record low snowpack. There's not a lot of historical weather data in our region, but we were measuring March snow depths at about 50% of previous low years. The Haines customs station received 41% of its mean winter snowfall.

Despite all this, **our forecast and educational programs were a big success this year.** We added an AIARE L1 course to the rotation, with very positive results. A big thanks goes out to the statewide AAIC team for all their efforts and support of our Haines program, and to our local staff, volunteers, sponsors, and partner organizations.

—Erik Stevens

Hatcher Pass Avalanche Center:

Avalanche information sharing in Hatcher Pass began Oct. 26th. Avalanche advisories ran mid-November, through mid-April. Persistent slab problems were 88% of advisories.

The shared observation platform with the CNFAIC, now in its third year, continues to grow and provides a simple and effective forum for the community to share Hatcher Pass observations. With a significant snowpack still in the mountains, observations continue to come in.

Unseasonably warm weather, winter rains into the upper elevations, strong wind events, light to moderate precipitation loads, and periods of cold clear weather characterize the season and its snowpack.

Snow came early in Oct and lasted well into May at Hatcher Pass this season. The SWE percent of POR (1981-2010) median as of May 13, 2018 is 153%. As of May 1, 2018, the Marmot snow stake at mid-elevation showed a base of approximately seven-feet of snow. In the alpine, winter is still here as we write this....

A very persistent weak layer formed in November. **Halloween Zombie Avalanche Cycle**, (HZAC,) was responsible for several near miss events resulting in partial burials. The associated weak layer cycled through activity, dormancy, and inactivity throughout the entire season. Looking through the 18-layer crystal ball snowpit of November, we knew we were in for an interesting avalanche season.

November also brought the unfortunate avalanche fatality of Randy Bergt, a well-known former Alta Ski Patroller, and experienced backcountry and nordic enthusiast.

February brought the Valentine's Day storm with two-feet of snow followed by broken hearts after hitting a moose with our truck. With the vehicle secured at a neighbors, the moose en-route to the next person on the moose road kill list for dinner, we hitched a ride and continued to HP that day to conduct stability assessments.

March was a combination of non-stop shoveling and great skiing/riding conditions. Marmot slide path ran with no involvement, crossing the road, and closing it on March 19th for the better part of a week. This was followed by an opportunity to work with DOT and the Daisy Bell, for its first appearance at HP, to mitigate Marmot avalanche paths.

We benefited from another season with a snowmobile thanks to the Alaska Mining and Diving Supply Ski-Doo BRP loaner program. This has allowed forecasters to broaden their coverage for observations and to mingle in the motorized community. It has also allowed us to assist with early season preparation of motorized trails with State Parks, and to have the machine available for emergencies.

We installed three '**Are You Beeping**' signs, with beacon checkers at popular roadheads up at Hatcher Pass. These are the first signs of their kind in Alaska.

In January HPAC participated in a collaborative joint education workshop with the Alaska Avalanche School and Friends of the CNFAIC with more than 100 people attending. In February we hosted another successful Cabin Fever Reliever Fundraiser with beer, bluegrass, bunny boots, and boogying at the Palmer Moose Lodge. Our newly formed HPAC advisory board made this event a HUGE success.

HPAC, with a nine-member Advisory Board, finished up the season with a strategic planning session. As of May 7, we continue to see buried PWL's re-activating in our deep snowpack.

—Allie Barker and Jed Workman, HPAC

Hatcher Pass: This persistent slab avalanche was triggered by the first rider who was caught, carried, and partially buried. The subject was able to deploy airbag in just enough time to make a difference between a partial and full burial. No injuries. Their partner helped dig them out. Hatcher Pass's continental snowpack posed significant assessment and decision-making challenges for many users this season. *Photo Jed Workman*

Valdez: Sculpted pencil-hard surface conditions near Thompson Pass, AK after two weeks of dry windy conditions. March 2018. *Photo Ryan Van Luit*

Valdez Avalanche Center (VAC):

The Valdez Avalanche Center issued **139 advisories** from October through April 2018. The one full-time and three part-time forecasters worked with three observers to collect and analyze field data.

Over the winter, Thompson Pass received 423" of recorded snow with 41" SWE. Valdez received 133" snow with 31" SWE. These values are within the twenty-year average.

Memorable weather events were an extended storm cycle in December and three long, dry, windy periods. Between December 2-20, two back-to-back storms dumped 103" of snow with 14" of SWE. After that, three wind events, exceeding 60 mph for durations of several hours or more, occurred while high pressure ridges dominated our region.

The common peak of our user season, mid-March to Mid -April, was almost void of new snow but the website still received 500 visits per day. An average of 300 people viewed the forecast each day throughout the season, with more than 45,000 views in total.

For the second year, from March 15 to April 15, VAC staff manned a temporary information kiosk near Thompson Pass offering educational courses and daily forecasting information three times weekly.

Sharing avalanche information since 2008, the Valdez Avalanche Center advisory continues to serve diverse groups of local, regional and international backcountry users with a broad spectrum of interests and experience. VAC membership has grown to 140 individuals, businesses, and community partners supporting the forecast and education programs.

This is the fifth year the City of Valdez allotted funding through the Community Service Organization program for Valdez Avalanche Center. Private sector businesses and individual member donations enable the program to grow from a solely volunteer effort, to paying qualified, trained forecasters and observers for their hard work.

— Ryan VanLuit & Sarah Carter

Closing:

The AAIC team continues to work to collaborate with other organizations to support avalanche information, education and research in Alaska. ▲

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