OCTOBER 2025 | ISSUE 7

BRING ON SURPRISE DAYS!

COMMUNITY SNOW OBSERVATIONS NEWSLETTER

Background image: “Four feet of fist to four-finger-snow on Mary’s Peak. Wild to ski soft pow 30 miles from the ocean.” - Dave Hill, CSO science team

CELEBRATIONS & TRANSITIONS

Last winter was a memorable one for our science team; we celebrated Katreen Wikstrom Jones who welcomed a winter baby and Nina Aragon who masterfully defended her PhD dissertation – with glam to spare! Nina has moved on to new adventures with M3 Works where she is continuing to apply her expertise through operational snow modeling aimed at quantifying water resources for decision makers across the western U.S. We thank Nina for her time with us; her energy and dedication to – in particular – advancing the modeling side of CSO. Read more from her on p. 7 and say hello to our new science team member and Oregon State University post-doc Zach Butler (p. 9)!

Outreach may have been a bit quiet last season, but the CSO spirit was alive and well! Your snow observations and ongoing participation kept the project thriving. Huge thanks to everyone! We're excited to rejuvenate CSO with new funding backing the project this year (p. 3), full staff capacity, and a continued wonderful group of partner organizations and volunteers who collect data and spread the mission of CSO.

This year's newsletter is jam-packed with interesting content – for example, read about snow mapping efforts in Alaska to better understand landslides (p.18), our new fluidless snow pillow instrument (p. 26), and the new rainy Sierra Nevadas (p. 28). As always we like to celebrate our ambassadors and we've included some ambassador content throughout the newsletter - don't miss the "Best Day of Winter 2024/2025" (p. 10).

We hope you enjoy this newsletter! If you have any questions or comments, contact us at **communitysnowobs@gmail.com**.

Follow us on Instagram **@communitysnowobs** and on X **@communitysnowob**

Check out our Youtube-channel for snow modeling up-dates

Skin track up through the rimed trees on Mary's Peak, Oregon. Photo: Dave Hill

THE NEW USBR PROJECT

BY DAVE HILL

Funding for snow science comes from many sources in the USA. The original funding for the CSO project came from the first round of the Citizen Science for Earth Systems Program (CSESP) in National Aeronautics and Space Administration (NASA). This program sought to fund projects that would (1) engage the public in making measurements related to Earth science and (2) would connect those measurements to various NASA initiatives. NASA is currently on its third round of this program and we all hope that it will continue in the future!

More recently the United States Bureau of Reclamation (USBR) has begun sponsoring research projects that focus on snow. The mission of the USBR is to *"manage, develop and protect water and related resources in an environmentally and economically sound manner for the benefit of the American public."*

In the western U.S. a large fraction of our water resources are derived from snowpack, so it makes sense that the USBR has a keen interest in understanding the 'when, where, and how much' of our snowpack. This led to the establishment of the Snow Water Supply Forecast (SNOFO) Program. The SNOFO program supports the advancement of snow monitoring technologies for the benefit of water supply forecasting (Fig. 1). The CSO project was very excited to be one of five recipients of SNOFO funding in late 2024.

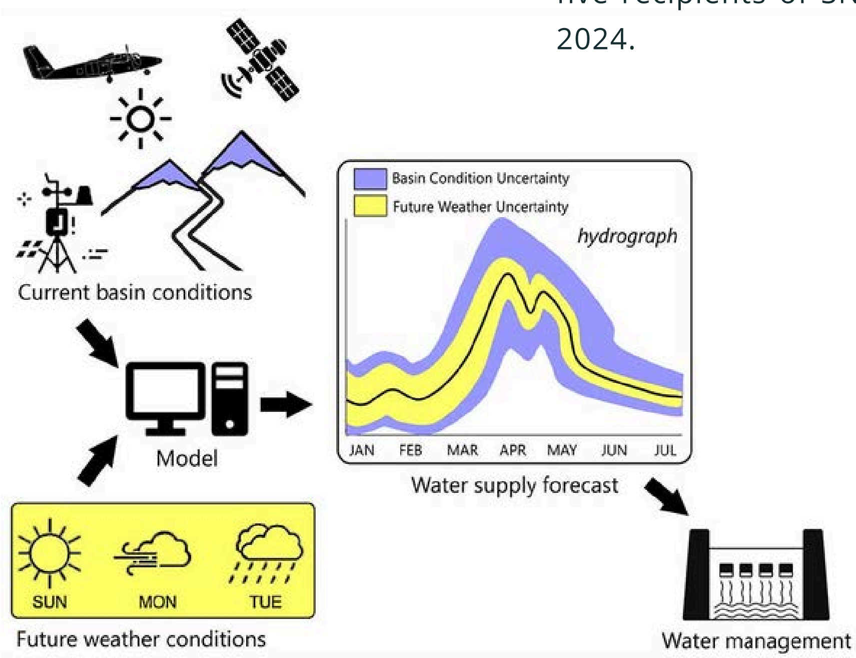


Figure 1. Conceptual graphic of how the USBR uses measurements and modeling to estimate water availability throughout the year. Source: USBR

The new funding for CSO will run from 2025 - 2028, and it will enable several things. First, it provides funding to keep CSO running in all locations (remember that you can view our modeling work at mountainsnow.org anytime!). Second, it provides funding for focused work in three domains (Colorado, California, and Oregon). This focused work has three parts:

First, we will collect high resolution airborne light detection and ranging (lidar) data in the Oregon domain (Fig. 2). This lidar data will cover the upper Deschutes River watershed (to the south of the Three Sisters and Mt. Bachelor) and will provide high-accuracy snow depth information on a very high-resolution spatial grid. The 'snow off' flight has already happened, and multiple 'snow on' flights will occur over the period of the project. These flights will provide some of the best glimpses of snow distribution in the Oregon Cascades.

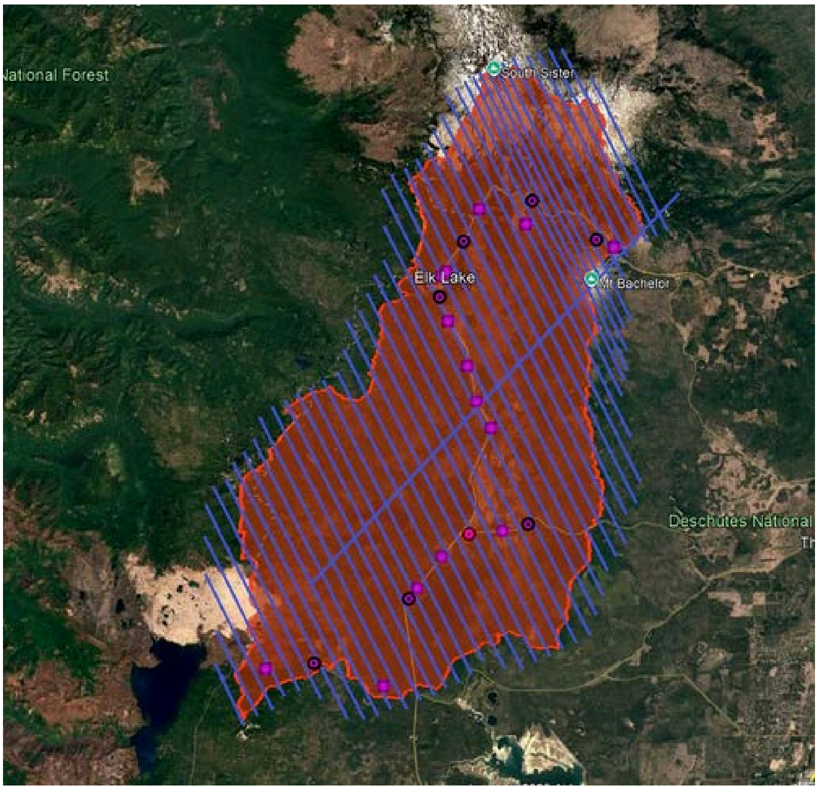


Figure 2. Image of the upper Deschutes watershed (pink polygon) west of Bend, Oregon. The blue lines show the tracks of the lidar flight that was carried out in August of this year.

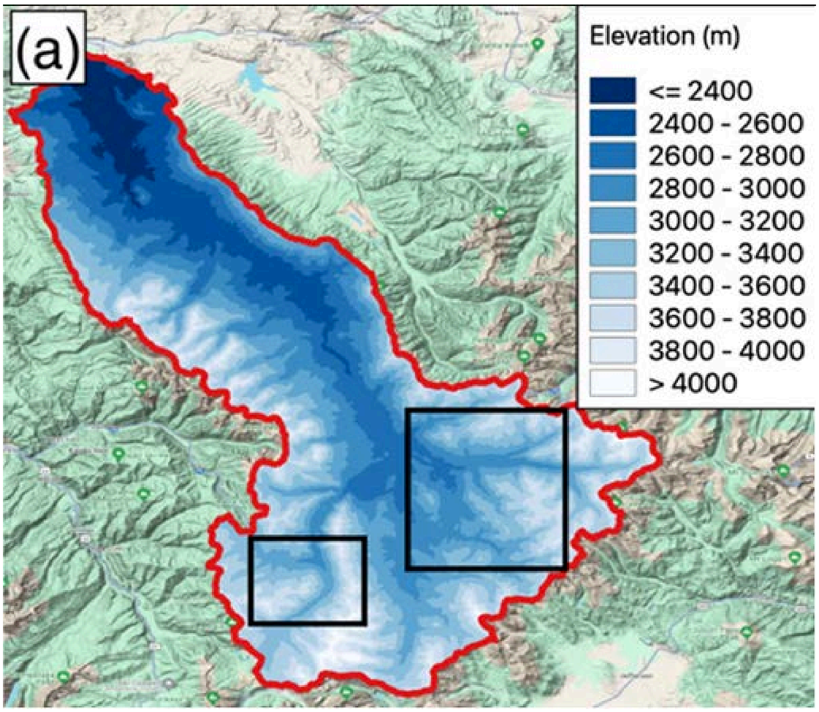


Figure 3. Blue River watershed (red polygon) in Colorado.

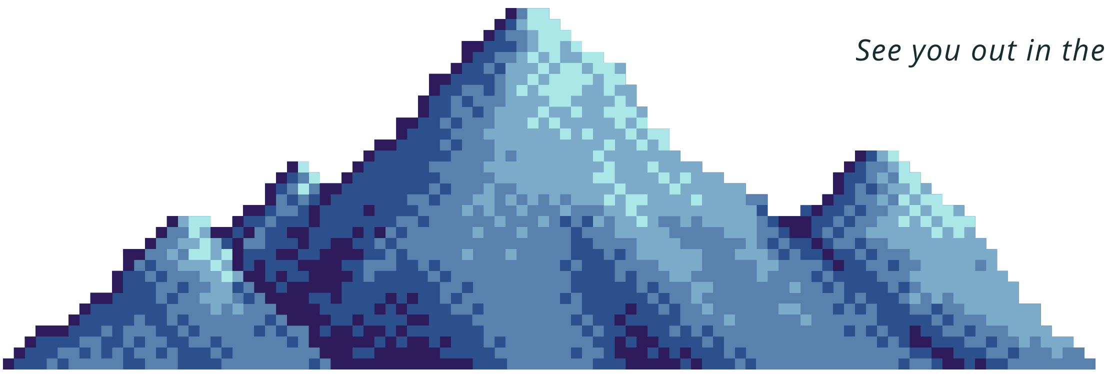
Second, we will study the ways in which snow information can be brought into snowpack models in order to make them better. Remember, the founding idea of CSO was that opportunistic measurements of snow depth from participants (on random days and in random locations) could improve snow models and we have shown that to be true! Well, now we will have in hand a very different kind of snow data. CSO observations are 'here and there' and 'now and then'. Lidar data is 'everywhere' but happens only infrequently (once or twice a year). So, can we combine these two very different sources of snow information in order to obtain even better models of snow distribution? That is our first scientific question of this project and we can't wait to see the outcome!

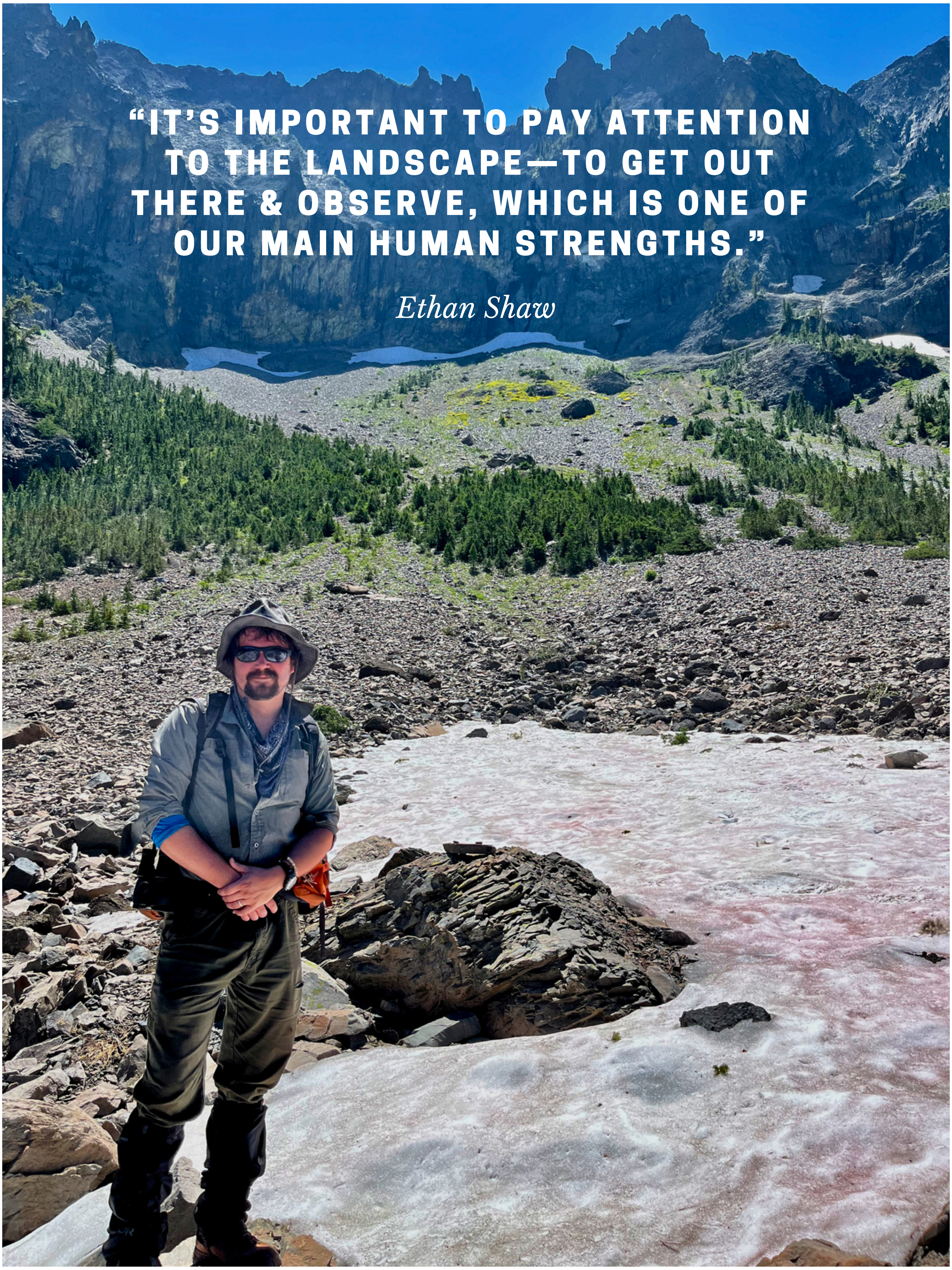
Third, we are interested in the question of 'how much lidar data is enough?'. Lidar flights are extremely expensive. While they are a great tool and they provide an unrivaled look at the distribution of snow in the mountains, is it possible to get 'good enough' model estimates of snow with less lidar coverage? As an example, see the figure above, which shows the Blue River watershed in Colorado (Fig. 3). One approach would be to do a lidar flight of the entire watershed and use that information to improve our snowpack models for the area. Our idea is that maybe we can instead fly only a 'sub-watershed' (see the black boxes as examples). We can take what we learn about the snow distribution in that smaller footprint and use it in our models. If we are successful with this idea, it means that we can take our lidar dollars and spread them out over more watersheds, maximizing the return on investment.

If you live in one of our three target areas and you want to learn more about how to participate please reach out to us at communitysnowobs@gmail.com. We have funding to provide small stipends (think gas money) to participants and we will of course be having data collection contests as in years past with swag from Backcountry Access for top participants.

We are thrilled to be able to rejuvenate CSO with this new funding source. It will allow us to answer some new and important questions about snow modeling efficiencies and it will allow us to keep collaborating with all of the tremendous CSO participants.

See you out in the snow!




"IT'S IMPORTANT TO PAY ATTENTION TO THE LANDSCAPE—TO GET OUT THERE & OBSERVE, WHICH IS ONE OF OUR MAIN HUMAN STRENGTHS."
Ethan Shaw

GOODBYE CSO!

BY NINA ARAGON

I recently defended my PhD, "Headwaters to Ocean: Improving Snow Monitoring, Distribution, and Runoff Estimates in the Context of Climate Change." As a doctoral researcher with Community Snow Observations, it has been a joy to watch the CSO program grow over the last 5 seasons. As part of the science team at CSO, I had the opportunity to engage with community-scientists, design and execute field campaigns, and develop workflows to assimilate CSO observations into snow models. This work helps us bridge gaps in automated monitoring networks and enables near-real-time mapping of mountain snow.

My work with CSO anchors a manuscript now in revision at *Water Resources Research*. Our results show that **incorporating opportunistic CSO measurements into our model not only fills observational gaps but also improves modeled snow-distribution estimates beyond assimilating station data alone** (see Fig. 1 on the next page). This has basin-scale implications for snow distribution and water storage. We'll share the paper once it's published.

After my defense, I joined M3 Works (M3W), a leader in operational snowpack modeling for water-resource management, which blends performance and powerful new research with the most validated snowpack model in the world. In collaboration with ASO, M3W's work includes real-time snow modeling for water stakeholders across western U.S. watersheds. I also contribute to historical modeling with partners such as the NRCS. I'm excited to continue research and to collaborate with the scientific community in this new role!

Nina together with Dave Hill on graduation day.

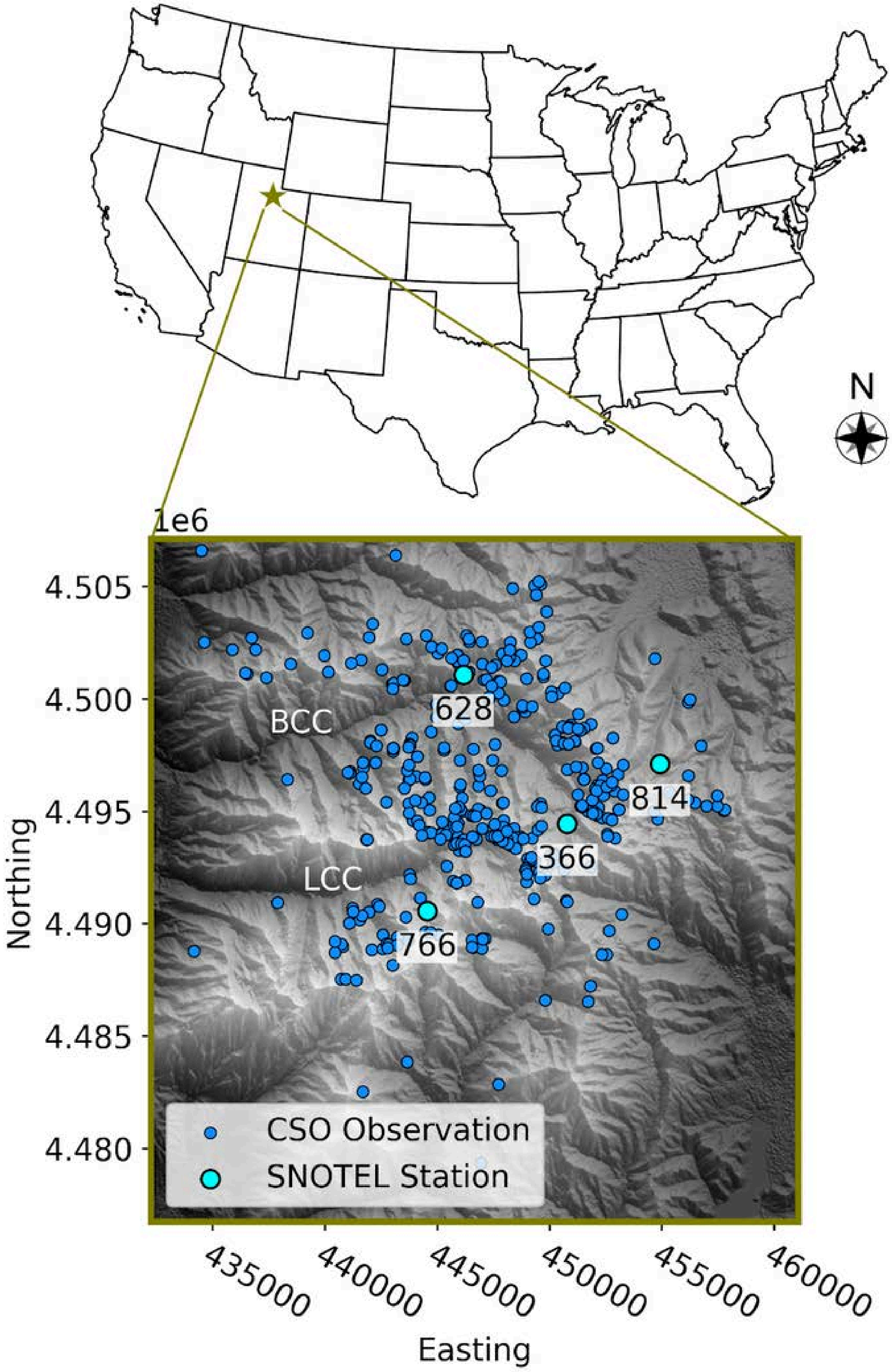


Figure 1 from WRR paper: Modeling domain map showing the location of all CSO observations from water years 2021, 2022 and 2023 in Utah and the location of the SNOTEL sites. Big Cottonwood Canyon (BCC) and Little Cottonwood Canyon (LCC) are labeled on the map.

This summer we welcomed Zach Butler to our science team! Here's a note from Zach:

I'M NEW HERE.

BY ZACH BUTLER

I'm really excited to join this project, building on CSO's strong foundation while bringing fresh ideas to the organization. Drawing on my PhD in Water Resources Science at Oregon State, I aim to advance snowpack modeling and connect that work directly to the CSO community. I also look forward to working with CSO members and becoming an integral part of this project.

I've been working with OpenSnow for 5 years as a meteorologist, where 2 of those years was forecasting the weather for Oregon. I forecast weather and snow conditions in remote environments, as well as write educational articles about weather and snow phenomena. I've seen firsthand how valuable in-situ observations are, not only for accurate weather/snow forecasting, but also for advancing scientific understanding of future conditions in mountain environments. I'm excited to build a relationship with OpenSnow and CSO, combining the best mountain weather forecasts with advances in snowpack modeling and observations.

Best Day of Winter 24/25

Sometimes a picture says more than a thousand words. Here are the days that ranked No. 1 last season for some of our ambassadors and science team members! As you'll learn, there can be a variety of reasons why *that* particular day was so memorable.

Hank Statscevich

While not technically in "winter," the highlight of my 2025 snow season was summiting Denali. On June 19 at approximately 6:45 p.m., my partner, Kevin Petrone, and I stood on top of The Great One. The journey took 15 days, hauling sleds, digging caches, acclimatizing, and enjoying excellent powder turns as we worked our way up and down the mountain. Reaching the summit was the culmination of an unforgettable adventure — one filled with challenge, perseverance, and moments of pure joy in the Alaska Range.

Dave Hill

Mt. Hood, Oregon, is a place of contrasts. On the south and southeast aspects, you have Timberline and Mt. Hood Meadows ski areas. Serving the greater Portland area, these ski areas drive a lot of skier-days (and traffic jams) throughout the winter and spring. And, Timberline keeps the skiing going through August, in most years, allowing literal hot laps via the Palmer lift. On the north side, you have the Cooper Spur, Eliot Glacier, and many of the harder, more committing climbing routes like the North Face Gullies. You have to work for those, however, since the access from the north requires thousands more vertical feet than the urbanized south side, it's well worth it, however.

The southwest and west aspects of the mountain are an interesting 'middle ground' and provide incredible ski touring when the conditions are right. The photo above is from my 'best day' this past spring. To access this area, you can skin up along the Palmer Lift out of Timberline, with the hordes of people looking to summit the mountain via the standard south side route. After 2500', take a break at the top of Palmer, rip your skins, and bid adieu as the climbers continue up towards the crater. Contouring hard right, towards Illumination Rock, you drop onto the Zig Zag glacier, and then pick your way down towards Paradise Park and Split Rock. This takes very careful route finding as there are countless gullies, ridges, and other features. This complex topography is a natural terrain park, and before you know it, you have dropped 2500’ and you are at Split Rock, which is the lunch spot of all lunch spots. →

After lunch, you will realize why you have seen nobody else in this spectacular location….you now have to skin 2500’ back uphill in order to get out! So, yes, it makes for a big day, but it is worth every sweaty step. You can find uncrowded winter adventures just about anywhere, if you are willing to look beyond the ordinary. Here’s hoping you find uncrowded adventures in the 2026 season.

Maddie Smith

My best day of winter was in Zermatt! My partner suggested we go there so that I could see "what was possible" in person. I study climate-related outdoor recreation impacts and Zermatt is a zero-combustion city. 🙂

Claudio Artoni

Here is one shot of myself teaching in an avalanche course in January 2025 in the Alps. It’s one of my favorites ‘cause I love to share the passion for the snow and build a safety culture in mountain goers.

Konstantis Alexopoulos

I am a snow hydrology PhD candidate from Greece. Together with CSO ambassador Mike Styllas we're currently working on a few key questions around the mountains of our home country, including a NatGeo project on the future hydrological functioning of small snow-fed alpine lakes on the Pindus mountain range.

Digging snowpits in the sunny alpine of Mt. Vardousia, Greece! The night before, we made an unforgettable approach under the stars, which, gave way to a brilliant day of snow-pit digging—and a few sneaky rounds of turns in between.

The data collected during the 2024–2025 season is allowing us, for the first time, to quantify snow's contribution to the country's water resources. At the same time, we're uncovering rates of snow loss that far exceed what we previously thought.

Katreen Wikstrom Jones

We welcomed our baby girl on December 27, 2024! Pictured to the right are my ski tips heading up Chair 6 just a day after I was cleared by the obstetrician for more strenuous exercise. Snow conditions weren't phenomenal at Alyeska Resort that day but the groomers were great! I put my ear pods in, scrolled to some of my favorite tunes to ski to, and skied a handful of laps during the hour, hour-and-a-half that I was away from the baby. Being able to go home and snuggle with my daughter afterwards just brought skiing to another level for me.

Tyler Miller

Electric Peak had been sitting on the list for years. Tallest in the Gallatin Range, remote, and rarely in condition. The approach alone is a commitment—16 to 18 miles round trip through tangled sagebrush and bear-thick drainages. You have to hit it just right: after the snowpack consolidates into something stable and predictable, but before the grizzlies wake and start combing the valleys for gut piles left from the annual indigenous bison hunt. It's a narrow window, and most years it closes before you get there.

This year, early March gave us that window. An unusually warm and dry fall had delayed winter's arrival, but when precipitation finally came in late December, it stuck—steady storms, mild temps, and a snowpack that held together. Zones that often go untouched for years, plagued by persistent basal facets and unreliable structure, were suddenly accessible. Electric was one of them.

I lined up with my two closest partners. People I trust to move fast, stay sharp, and keep the mood light. We started early, skinning through crusted meadows and shaded timber. Baselayers in the valley, but the cold crept in fast. By the time we hit the alpine, it was finger-numbing. Transitions were quick and quiet—no wasted motion. *Next page →*

Before the final push, we dropped packs on the west shoulder, found shelter from the wind, and ate our snacks before putting on our crampons and getting out our ice axes for the next 500’ to the summit. The summit wasn’t clean. It was wind-scoured and raw, but beautiful. Views for miles. The Grand stood proud to the south. Pilot and Index to the east. Lone Peak to the west. The Crazies and Absarokas stretched out to the north.

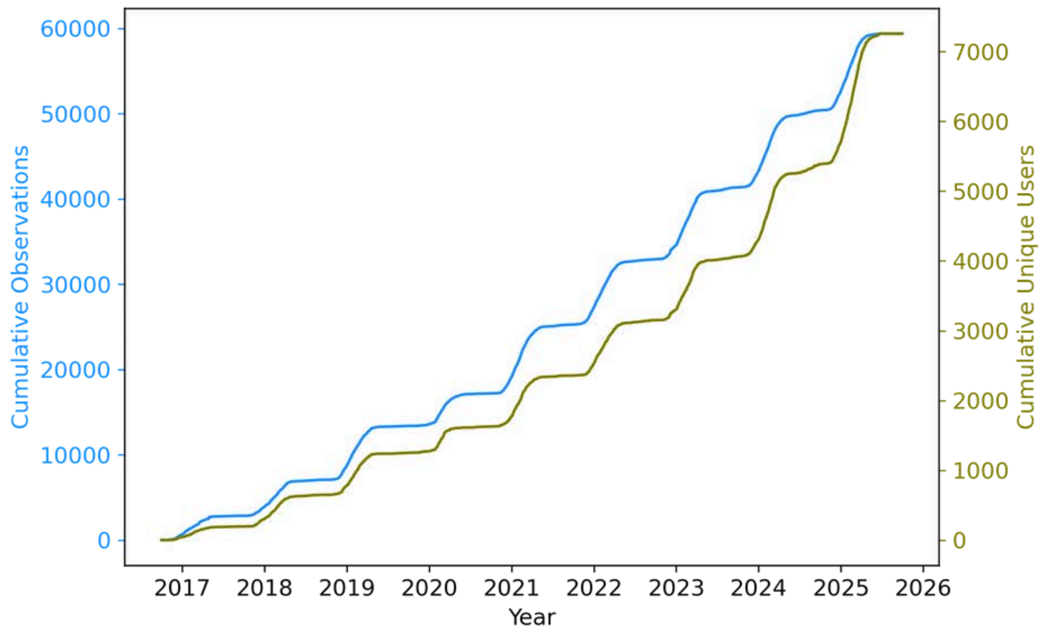
Then came the descent. The East Dog Leg Couloir—Electric’s classic line. Snow was mixed: wind buff up high, breakable crust mid-way, and pockets of soft snow near the bottom. A few turns in the sparsely located pow felt like a gift. It certainly wasn’t the kind of run you ski for style points, but the kind you ski for the story. (Something most ski mountaineering adventures emulate).

The egress was smooth. No gear failures, no route-finding hiccups. Just steady movement through terrain we’d earned. Near the bottom, we spooked a bachelor herd of bull elk—antlers flashing, bodies moving fast through the sage. A final reminder that this place belongs to something older, wilder. We followed fresh wolf tracks through the last stretch, the prints clean in the softening snow.

It wasn’t the best skiing I’ve ever had. But it was one of the best days. Years on the list and several attempts, finally clean. Shared jokes, summit high-fives, and a line that gave us everything we asked for. Electric Peak didn’t just get skied—it got respected.

SEASON STATS 2024-2025

We’re happy to report that winter season 2024-2025 showed strong increase in number of snow observations and even stronger increase in the number of individual participants submitting observations to CSO! Keep it up this winter folks!



Cumulative observations and unique users over time.


"EVERY DAY, I TRY TO REMIND
MYSELF ABOUT HOW BEAUTIFUL
THE SMALL THINGS CAN BE."
Emily Tidwell

UPDATES FROM PROPAGATION LABS

BY GARRETT HARMSEN

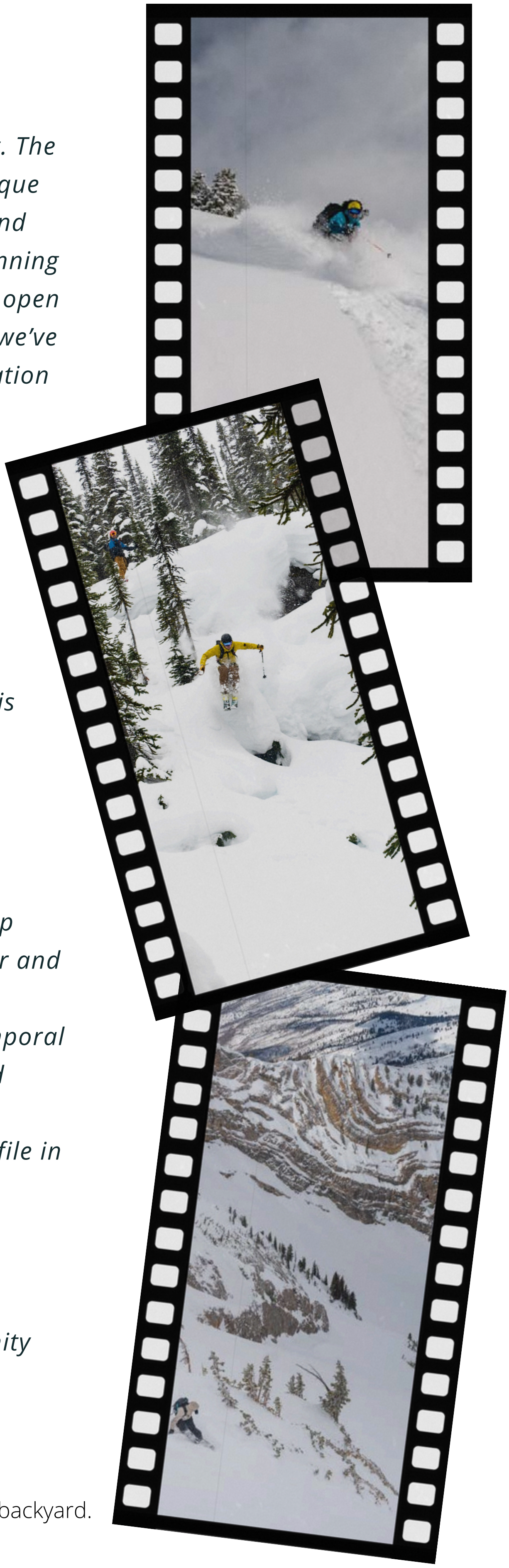
At Propagation Labs, we're inspired by the power of community snow observations through the CSO project. The thousands of submissions each year are building a unique public dataset that's advancing both snow hydrology and avalanche safety research. While CSO is our longest running research partner, we want to make it clear that we are open to many types of scientific collaborations. To this end, we've made it even easier for scientists to access the Propagation Labs database. Our improved API now provides direct access to more than 10,000 public snow profiles, stability tests, and observations. If you're working on a research project and would like access, please reach out.

We're also encouraging more cracking and collapsing observations. These quick, geotagged records are critical for understanding exactly where the snowpack is unstable. The Utah Avalanche Center is already using this information in their snowpack stability modeling project, and contributions from observers in Utah are especially valuable.

Outside of research projects, we've been focused on app improvements to make observation recording smoother and analysis more powerful, including:

- *New snow visualization tools - see spatial and temporal trends in test results, snowpack characteristics, and stability indices*
- *Improved Voice to Pit functionality - Describe a profile in your voice and the app will draw your profile*
- *Translations into French, Italian, and Spanish*
- *Many other smaller improvements!*

We're grateful to continue supporting the CSO community and look forward to another winter of deep snow and many more observations!



Photos: Joe and Garrett skiing their backyard.

SNOW MAPPING FOR LANDSLIDE MONITORING AT UPPER BARRY ARM FJORD, ALASKA

BY KATREEN WIKSTROM JONES

Prince William Sound (PWS) in southcentral Alaska features snow-capped mountains, glaciers, and deep fjords. Rapid warming is driving glacier retreat and permafrost degradation, producing a dynamic paraglacial landscape. In the Upper Barry Arm several deep-seated landslides have been identified, the largest—“Landslide A”—spanning ~2 km in width with an estimated volume of ~500 million m³ (Fig. 1), which could generate a tsunami across PWS if it failed.

The Barry Arm landslide is strongly influenced by water—it responds to heavy rainfall, snow melt, and the complex water system tied to Cascade Glacier. Since it was identified in 2020, the site has been closely watched through a joint effort using both remote sensing and on-the-ground tools like lidar, radar, mapping, seismic and infrasound sensors, and weather stations.

By studying five years of data, researchers have been able to track how the landslide is moving, understand how nearby features like the Cascade Glacier’s water system influence it, and see how it reacts to outside forces such as heavy rainfall and rapid snowmelt.

Rainfall intensity is often used to assess landslide probability, but in cold climates precipitation falls largely as snow. Snow adds weight, it insulates the soils underneath and meltwater from snow seeps into the soils, all of which can either help to stabilize or destabilize the unstable slope depending on soil properties and pre-snow conditions. Despite snow’s importance, snowmelt dynamics are rarely integrated into

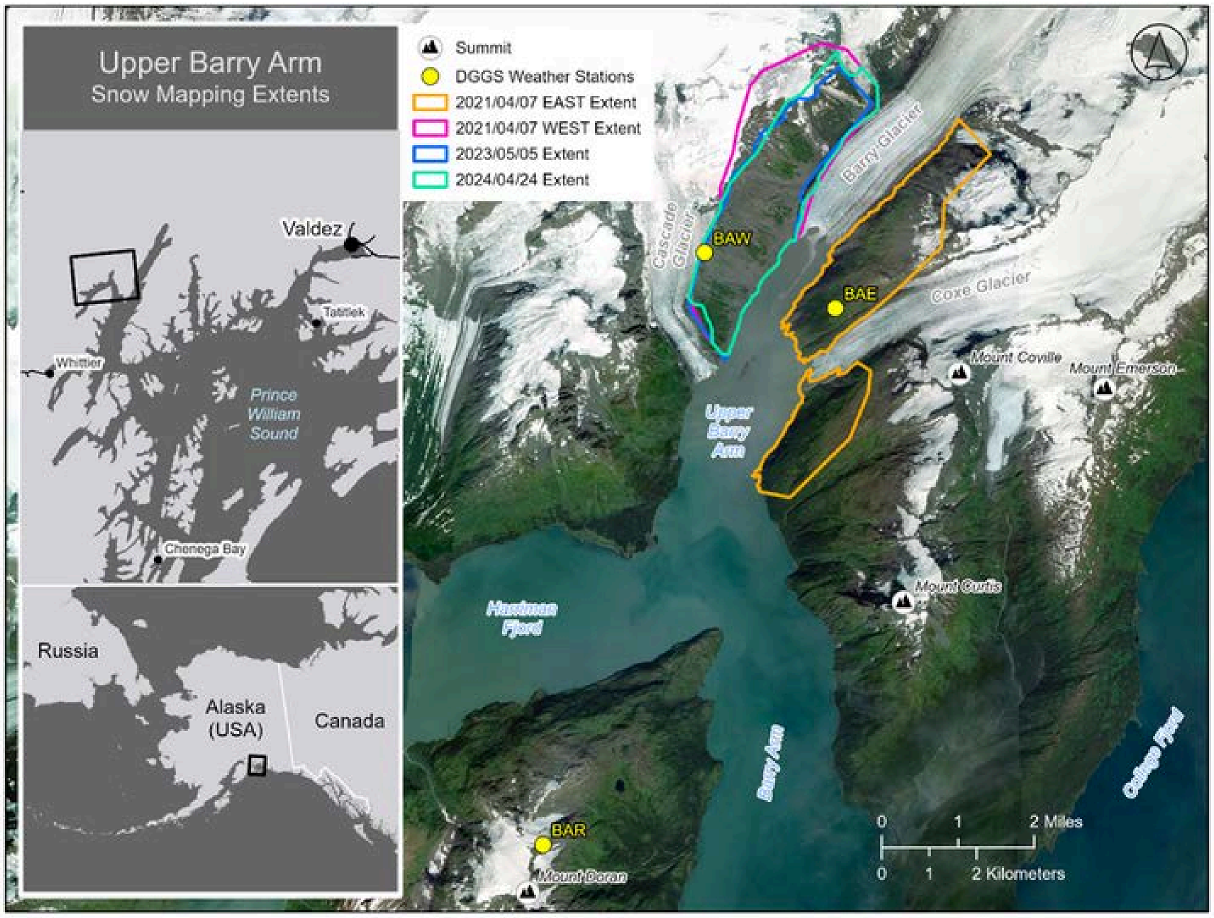


Figure 1. Location map of Upper Barry Arm and the snow mapping extents for the time period considered in this study.

regional landslide early warning systems. Real-time air temperature data can help forecast snowmelt thresholds when combined with snowpack and landslide records. Tracking the amount of heat, layers, and water in the snowpack is also key to making better forecasts.

The relationship between snow and deep-seated landslides remains less understood. These systems respond more slowly to snowmelt than shallow slides, complicating prediction. While it has been observed that landslide movement at Barry Arm can be linked to heavy rainfall and rapid snowmelt, the timing of responses remain uncertain.

Consistent with a maritime snow climate, mid and upper elevations in Upper Barry Arm remain snow-covered throughout the winter, whereas lower elevations alternate between snow-covered and snow-free conditions depending on air temperature during snowfall events. Snow accumulation is highly variable, controlled by elevation, aspect, orographic lifting, and prevailing winds. Liquid water is released both through spring–summer snowmelt and mid-winter rain-on-snow (ROS) events.

A localized, catchment-scale understanding of snow-driven hydrological responses and climate change impacts in Alaska remains limited. Alaska Division of Geological & Geophysical Surveys (DGGS) has collected multi-year lidar data since 2021 at Upper Barry Arm fjord with the aim to characterize snowpack distribution; a critical step in validating snow model output and improve our understanding of its role in landslide activity. In the summary presented here, we highlight some of the findings of that work which will be published later on as a Report of Investigation and available for download at DGGS's website here.

As our primary methodology we flew lidar surveys using a fixed-wing airplane and collected 'snow off' (bare ground) surface elevation data during the summer or fall season and 'snow on' surface elevation data during the winter near our estimated date of peak snow height. To support the lidar mission, we set out a Global Navigation Satellite System (GNSS) base station on the island below Landslide A. We collected ground control points within the area to use for processing and quality assessment and control (Fig. 2). To obtain snow height information we did simple raster algebra in GIS and subtracted summer 'snow off' elevations from winter 'snow on' elevations.

Figure 2. (Left) Ronald Daanen (*In memoriam*) collects ground control points on the east side, April 7, 2021, to use for lidar point cloud validation. Barry Arm landslide in the background. (Right) Location of GNSS base station supporting the lidar survey on May 5, 2023. Photos: Wikstrom Jones

We mainly focused on the west side of the fjord, i.e. the landslide. We flew ‘snow on’ surveys on April 7, 2021, May 5, 2023, and April 24, 2024. For the east side of the fjord we only flew on April 7, 2021. In addition to flying lidar, we did two ground measurement campaigns near the weather stations (Fig. 3) on each side of the fjord on April 7, 2021, and on May 5, 2023. We measured snow height using an avalanche snow probe and recorded those data points in the ***Snow Scope*** mobile app (you’re familiar with those observations for CSO!). We also measured snow water equivalent (SWE) using a federal snow core (Fig. 4).

We produced snow height distribution maps, calculated snow metrics and elevation-based snow height gradients, and analyzed weather station data.

Figure 3. Snow height measured by a Campbell Scientific Sonic Ranger 50 at BAW above Landslide A.

Figure 4. (Left) A snow probe is stuck into the snow to measure snow height, on April 7, 2021, above the landslide. (Right) An extracted snow core is measured and weighed to estimate snow water equivalent. In this photo taken during the field campaign on May 5, 2023, we verify that we reached the ground by seeing this “dirty bottom”. Photos: Wikstrom Jones

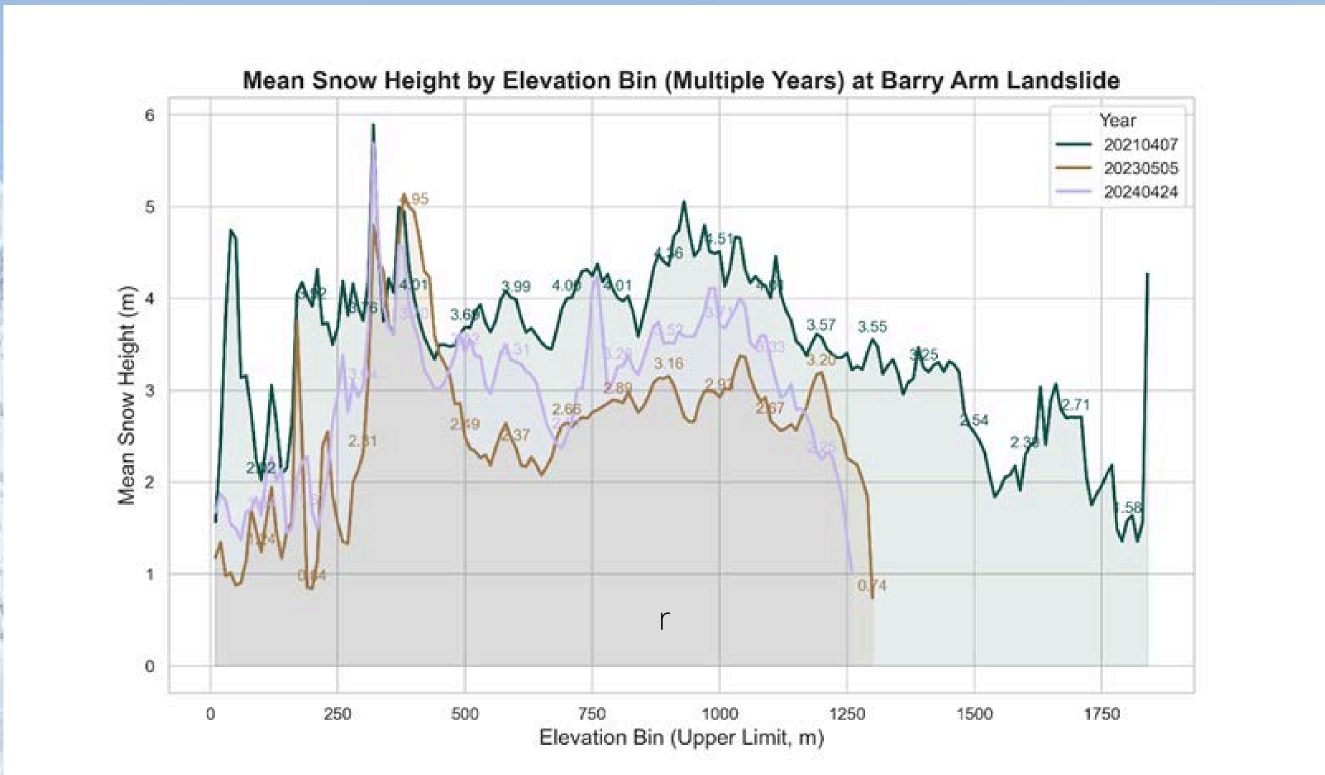


Figure 5. Elevational snow height gradients for Barry Arm West (landslide) based on the 4/7/2021, 5/5/2023 and 4/24/2024 lidar acquisitions, averaged for 10 m elevation bins. Annotated snow heights at every 100 m.

On the west side of the fjord (landslide), snow depth is influenced by wind and avalanches, which move snow around depending on the terrain. In spring, this east-southeast-facing slope also gets drenched in sunlight that causes fast melting of snow. Near sea level, deep snow are represented by avalanche debris, while the deepest untouched snow is found between 750 and 1000 meters above sea level (m asl) (Fig. 5).

We analyzed snow height patterns using cluster analysis from April 7, 2021, and May 5, 2023, but left out April 24, 2024, because the data were incomplete. When comparing results, it's important to note that the 2023 survey took place a month later when melting had already reduced the snow cover. The clusters in Fig. 6 represent distinct spatial patterns of snow accumulation and interannual variation: Class 1 corresponds to consistently shallow snow zones, often exposed or wind-scoured areas; class 2 and 3 represent a low to moderate snow region; and class 4 and 5 are deep- and very-deep-snow areas, likely corresponding to sheltered deposition zones or avalanche runouts. This classification captures both absolute snow depth levels and their relative year-to-year patterns (Fig. 6).

For 2021 we used an average snow density of 40% based on our field measurements in wind-affected snow along the ridge. We used an avalanche debris density of 63% (600 kg m^{-3}) from the literature and applied to the two main avalanche chutes. Combined we obtained a total SWE of 8.19×10^6 m^3, with avalanche debris representing 53% of total SWE on the slope (west side).

The east side lacks complicated avalanche terrain, resulting in less snow moved by avalanches from high to low areas (Fig. 7). Snow height increase follows a clear gradient from sea level to ~700 m asl (~50 cm per 100 m) where it becomes more variable due to exposure to the weather elements – *wind* (Fig. 8).

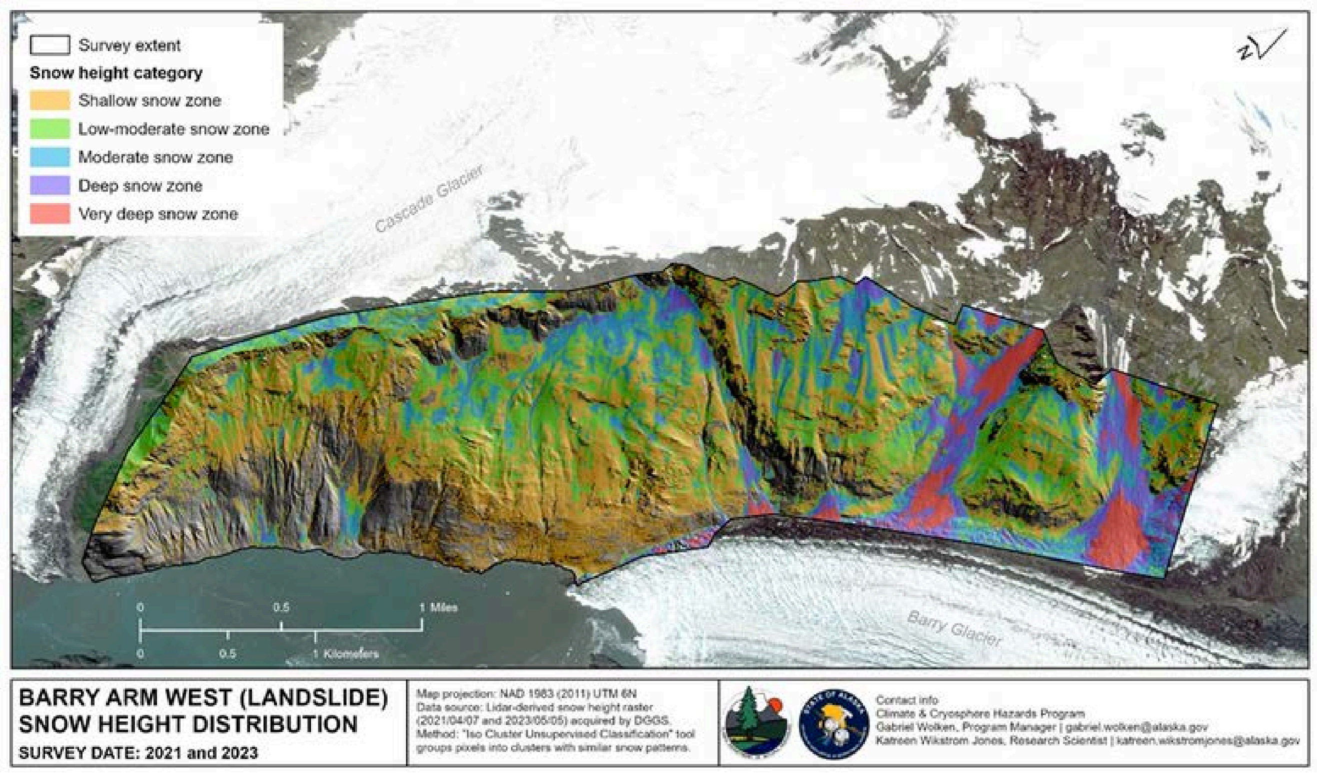


Figure 6. Cluster analysis results indicating snow height patterns at Barry Arm West (Landslide) using lidar-derived snow height from April 7, 2021, and May 5, 2023, classified and interpreted into five snow height categories. April 24, 2024, was excluded from this analysis due to patchy coverage.

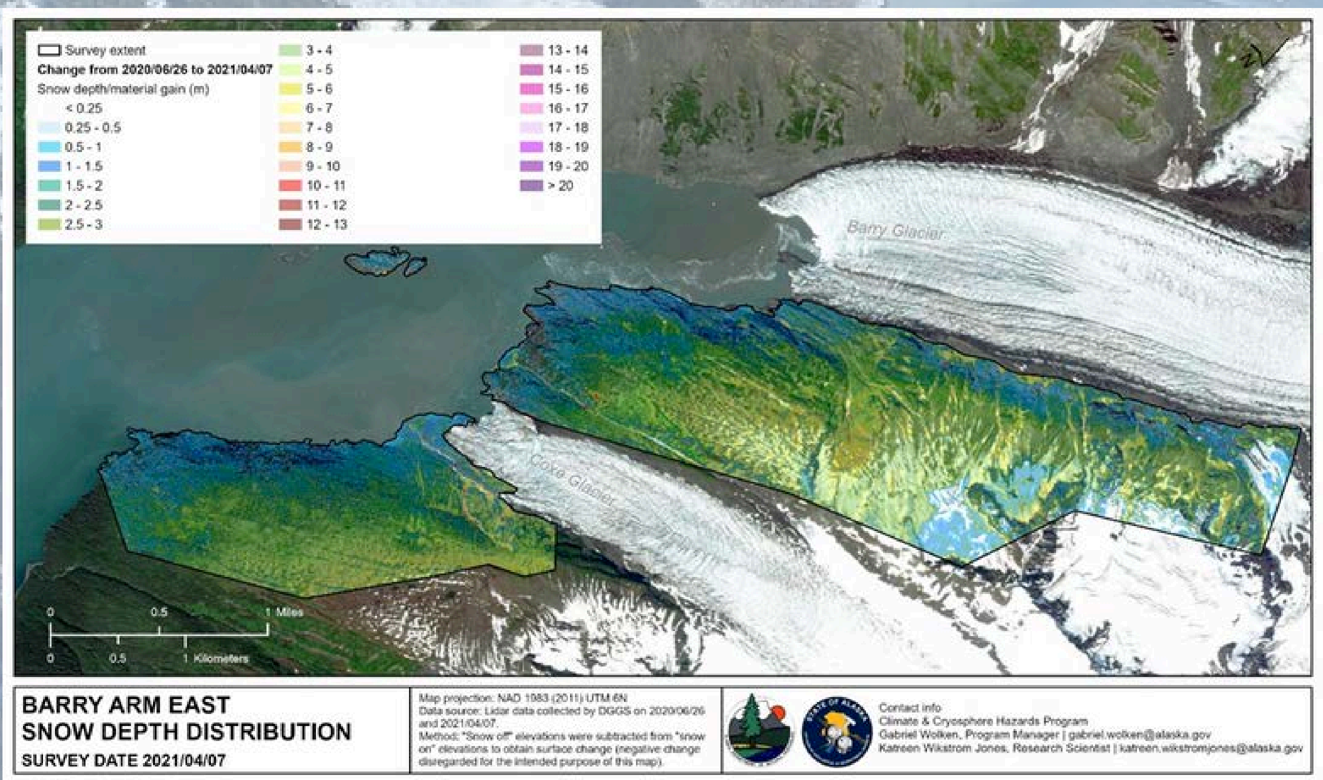


Figure 7. Snow height at Barry Arm East on April 7, 2021, using June 26, 2020, as 'snow off' reference.

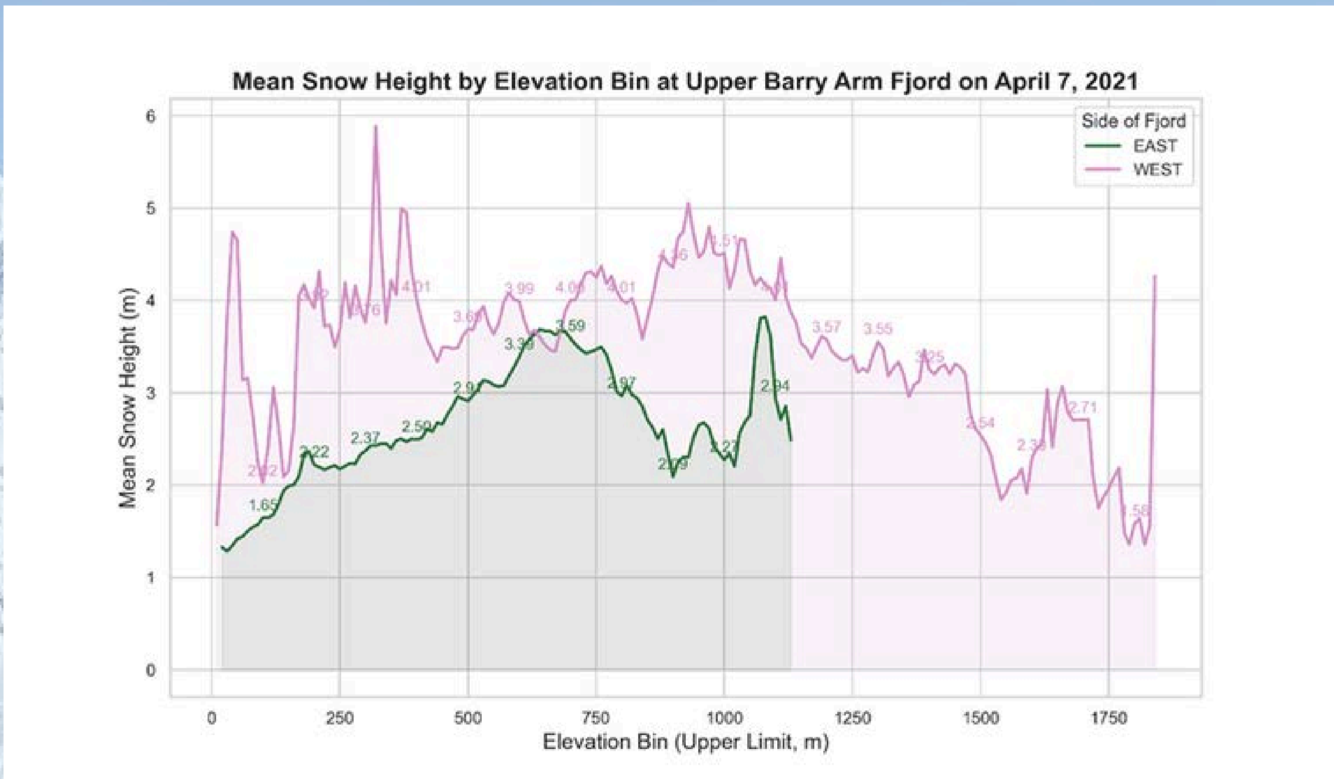


Figure 8. Elevational snow height gradient for Upper Barry Arm fjord West (landslide) and East on April 7, 2021. Snow depth estimations are based on "snow off' datasets acquired on October 16, 2020, and on June 26, 2020, for the west and east side respectively. Annotated snow heights at every 100 m.

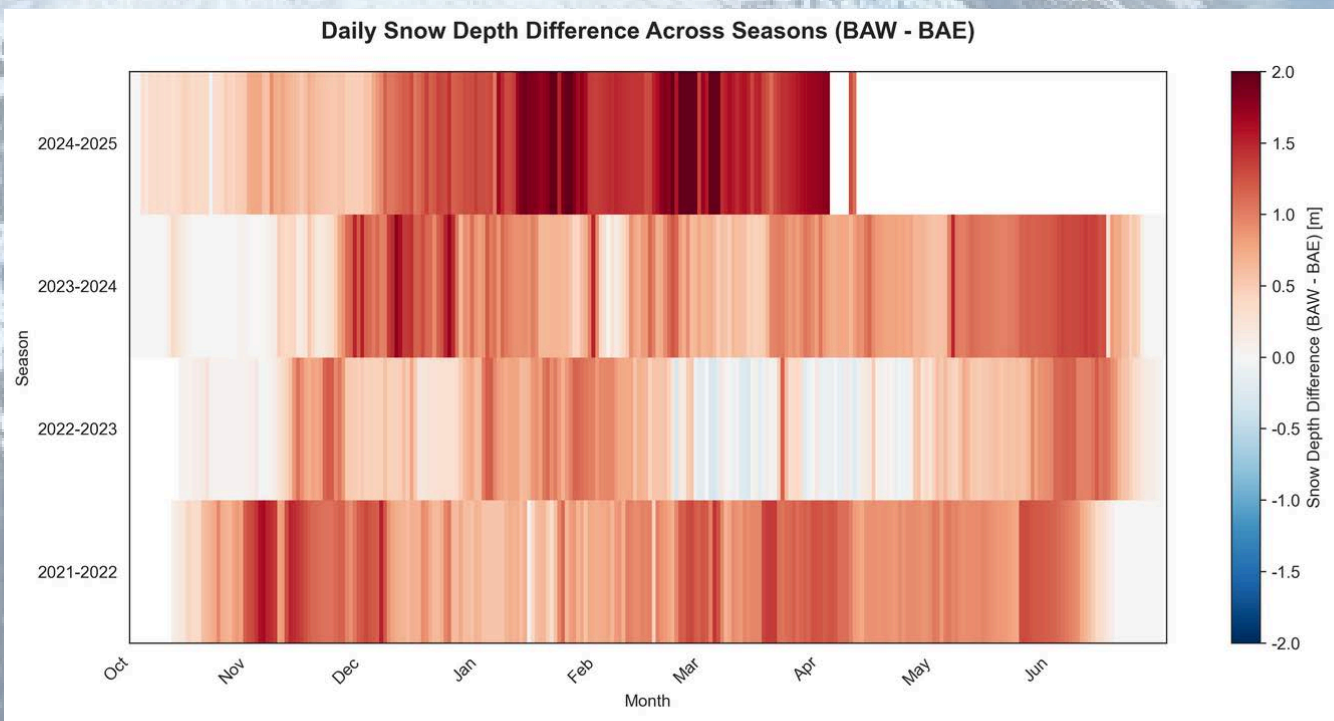
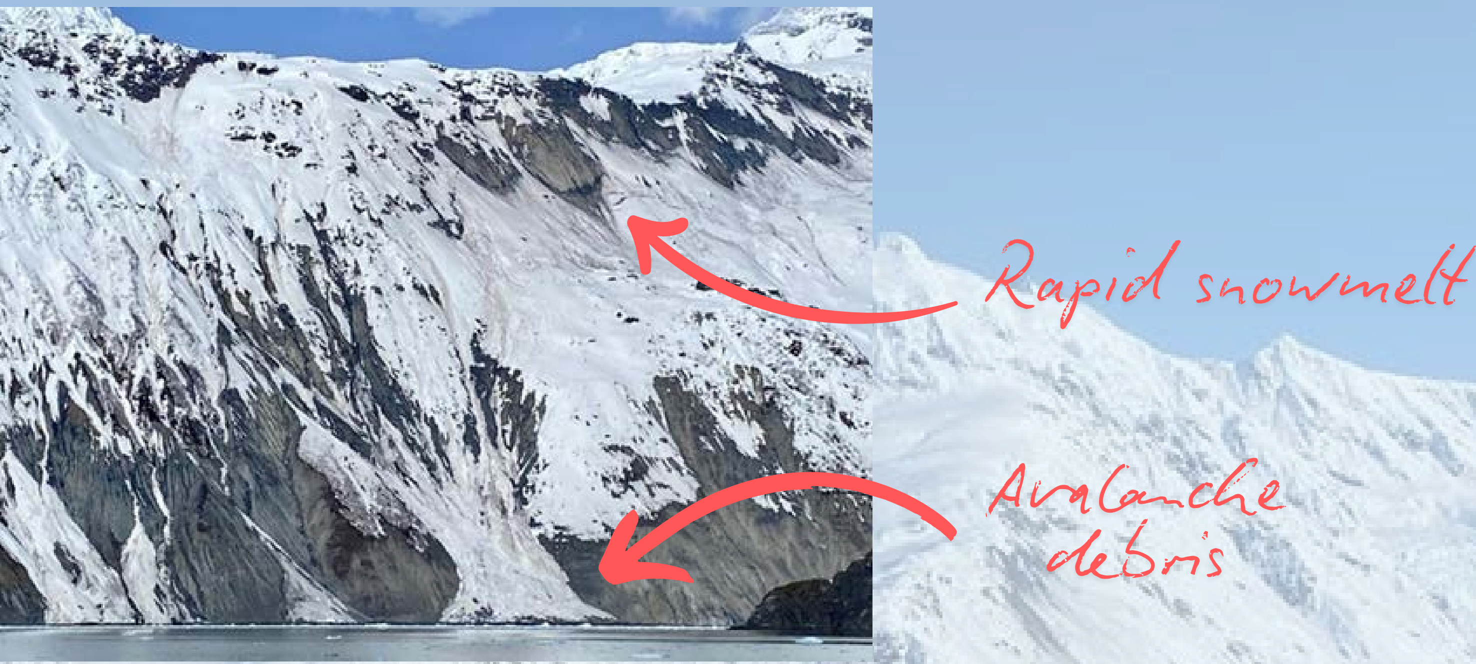


Figure 9. Difference in daily average snow depth at Barry Arm West (BAW) and Barry Arm East (BAE) weather stations across all seasons of record. BAW stopped operating in middle of April, 2025.

In 2021, we installed two weather stations at Barry Arm; one on the west side above the landslide at 1024 m asl (BAW, see Fig. 2) and one on the east side at 565 m asl (BAE) (Fig. 1). We calculated the average daily snow depth at each station and plotted the difference to highlight *when* during the winter season, snow height accumulates



differently between the two sides. We observe that snow height increases with elevation due to orographic lifting (Fig. 8), but there are many processes that can disturb or redistribute snow throughout the winter. With the plot displayed in Fig. 9 at hand, we can compare time periods that stand out (red or blue) to weather systems that impacted the area. *Could strong winds have lifted and redeposited snow near the BAW station? And was it warm, sunny weather that melted the snow quickly at BAW while the BAE snowpack held on a bit longer?*

Interestingly, the peak snow height date differed wildly between BAW and BAE. For winter 2021-2022, peak date was one month earlier at BAW than BAE, but the next year it was one month later. In 2023-2024, peak dates were only one day apart, whereas last winter (2024-2025), peak date for BAW was January 26, whereas for BAE it was April 11. This highlights the complexity of snow distribution and the challenge of timing lidar missions near peak snow height.

A 50-year record of seasonal snow for Alaska shows that snow cover duration is decreasing with more precipitation falling as rain in the fall and spring. While the overall trend shows decline, extreme winter storms can temporarily increase snow height. In the coming decades, climate models suggest less snowfall at low and coastal elevations, but more extreme snowstorms affecting higher elevations (above 1000 m). This will create uneven snow patterns across the landscape and could raise the risk of landslides, especially with the predicted increase in mid-winter rain-on-snow events.

Why does our work in Upper Barry Arm fjord matter? Our study serves as a valuable data record for climate model validation and as input to hydrological and landslide prediction models. Our study characterizes differences in snow distribution depending on aspect and topographic features which is important for understanding slope instabilities. With only a 3-year record we see clear patterns: snow depth increases with elevation depending on precipitation form (rain or snow), wind picks up and deposits snow in favorable locations, and avalanches move snow from high to low elevations throughout the season.

FLUIDLESS SNOW PILLOWS

BY DAVE HILL

Snow data comes in many forms, from many different places. Remotely sensed snow data comes from platforms that include drones, airplanes, and satellites. These data sources have many advantages that include large spatial coverage and high spatial resolution. In-situ snow data comes from individuals (CSO participants!) who go out into the snow and make a direct measurement. These 'in place' data sources also include automated snow monitoring stations, maintained by the Natural Resources Conservation Service.

So-called SNOTEL (Snow Telemetry) stations commonly measure temperature, humidity, snow depth, and snow water equivalent. In the United States, we have 800+ SNOTEL sites that cover the western part of the country and create one of the premier sources of snow data and information. This dataset is incredibly useful to water managers and also the recreational community that wants to know where the snow is, and how much of it there is!

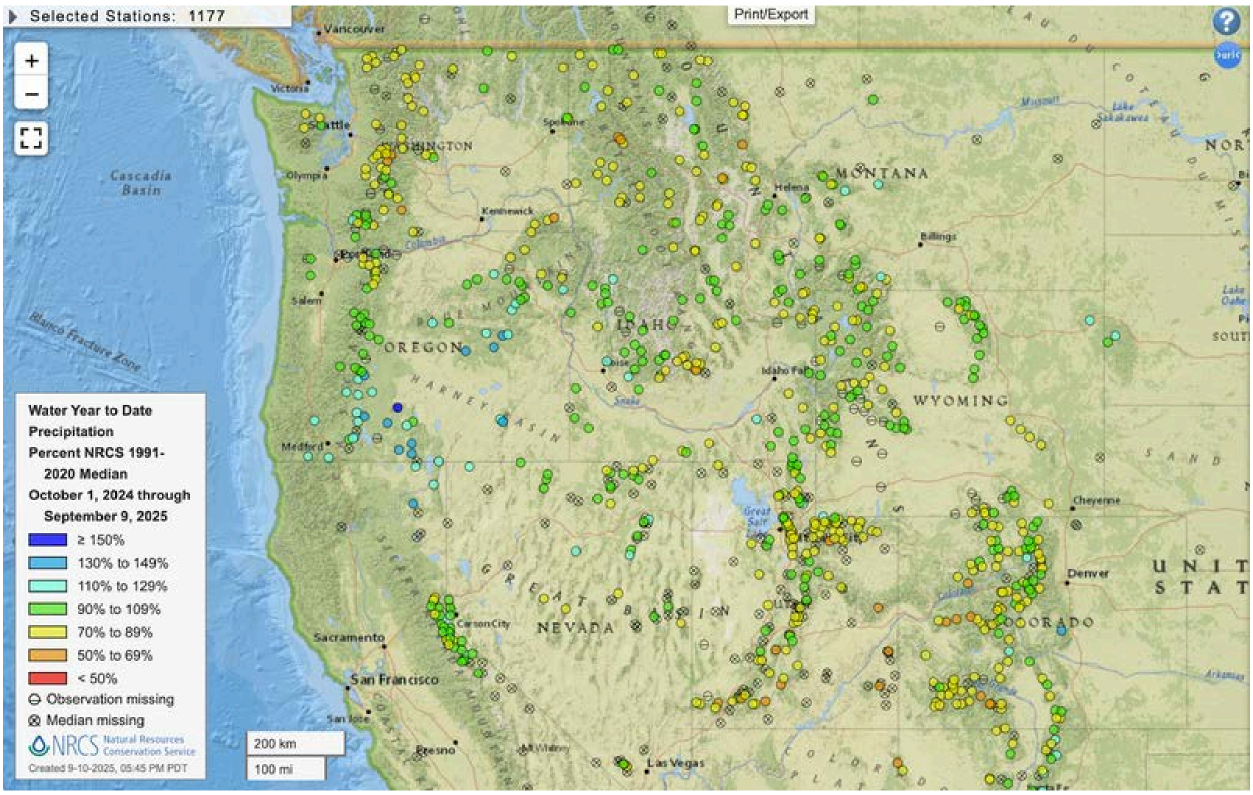


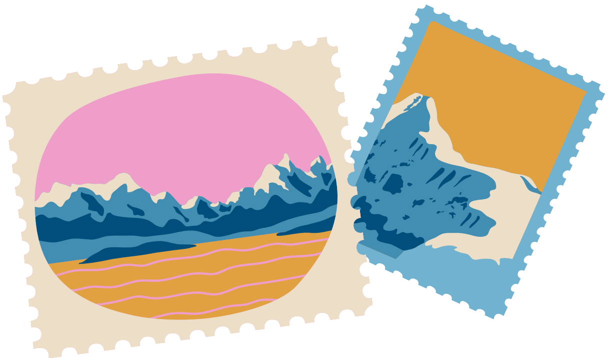
Figure 1. Map of the western U.S. showing the locations of Snow Telemetry sites that measure snow depth and snow water equivalent. Additional stations are located in Alaska.

At most SNOTEL sites, the 'water equivalent' of the snowpack (the depth of water you would get if you melted the snowpack) is measured with what is called a snow pillow. This snow pillow is commonly a thin bladder that contains a mix of water and anti-freeze. As the snowpack builds up on top of this bladder, the pressure increases and can be recorded with a data logger. Really, the snow pillow is nothing more than a large and expensive bathroom scale.

Figure 2. Example of a typical Snotel Telemetry station with a fluid-filled snow pillow on the ground.

Through a grant from the Oregon State University, the CSO team recently obtained a 'fluidless' snow pillow. The principle is the same, in terms of weighing the snowpack to determine how much water is in it. The operation is different however. These fluidless pillows use electronic load cells to determine weight. This instrument will be installed at Mt. Bachelor (Oregon) this season, in cooperation with the Mt. Bachelor staff (thank you!). This location is higher than any other station in Oregon that measures snow water equivalent. In this way, this new equipment will add a valuable data point to what is known about the snow water resources in the Oregon Cascades and will directly benefit the new U.S. Bureau of Reclamation project that CSO has just started.

Figure 3. A 'fluidless' snow pillow assembled on the campus of Oregon State University.



From Sierra Nevada to Sierra Lluviosa

B Y D R . E L I Z A B E T H B U R A K O W S K I

U N I V E R S I T Y O F N E W H A M P S H I R E

The first and only time I have been riding in the Sierra Nevada was in December 2016. I was in Tahoe to present climate science to a group of professional athletes at the 2nd Protect Our Winters Annual Summit. Before our morning session of talks on climate change and advocacy, we set out as a group for a warm-up on the slopes.

I had packed my splitboard (at the time my only snowboard in my quiver) in hopes of some off-piste adventuring. The snow stars did not align on this trip, and instead I had my first encounter with an amalgam of machine-made snow and hardened Sierra Cement. The forest floor in between trails was bare, and we were confined to the ribbons of white that threaded down a partially open Palisades Tahoe.

Jeremy Jones, the founder of the small non-profit who brought us all together

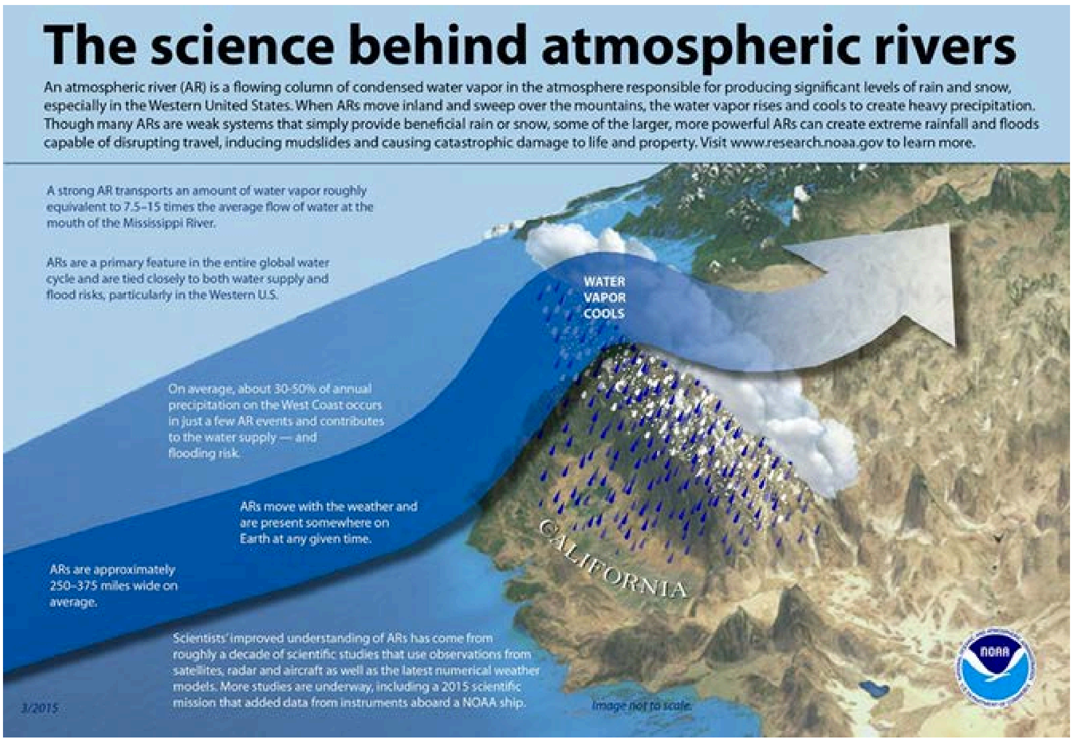


Figure 1. Schematic of how atmospheric rivers impact the landscape. Source: NOAA

for the summit, noted out loud that today was not the ideal Tahoe powder day, but instead a "skills" day. The conditions more closely approached the "East Coast ice" I had been raised to ski and ride on in New England.

In the months that followed December 2016, mother nature delivered record-breaking snowfall in a series of back-to-back atmospheric rivers. These long, narrow bands of concentrated water vapor deliver massive amounts of rain and snow that originated in the tropics. The rivers in the sky are about 250-275 miles wide and can be over 1,000 miles long. When they encounter land, the water vapor condenses into rain at lower elevations above freezing and snow at higher elevations below freezing.

At Palisades, January alone accumulated 278 inches (over 23 feet!) of snow at 8,000 feet. The winter total of 712 inches (almost 60 feet!) kept the lifts turning at Palisades Tahoe until the 4th of July in 2017. Following on the heels of drought years in 2014-2015, the lake level in Lake Tahoe rose six and half feet when the snow melted, the highest increase in a single season.

While this was at the time* a record-breaking snow year for Palisades Tahoe within the past 25 years, longer term snowfall records at Donner Pass show that 2016/17 (47.7 feet) barely cracked the top 20 since record keeping began in 1879.
*Palisades Tahoe record snowfall broken again in 2022/23

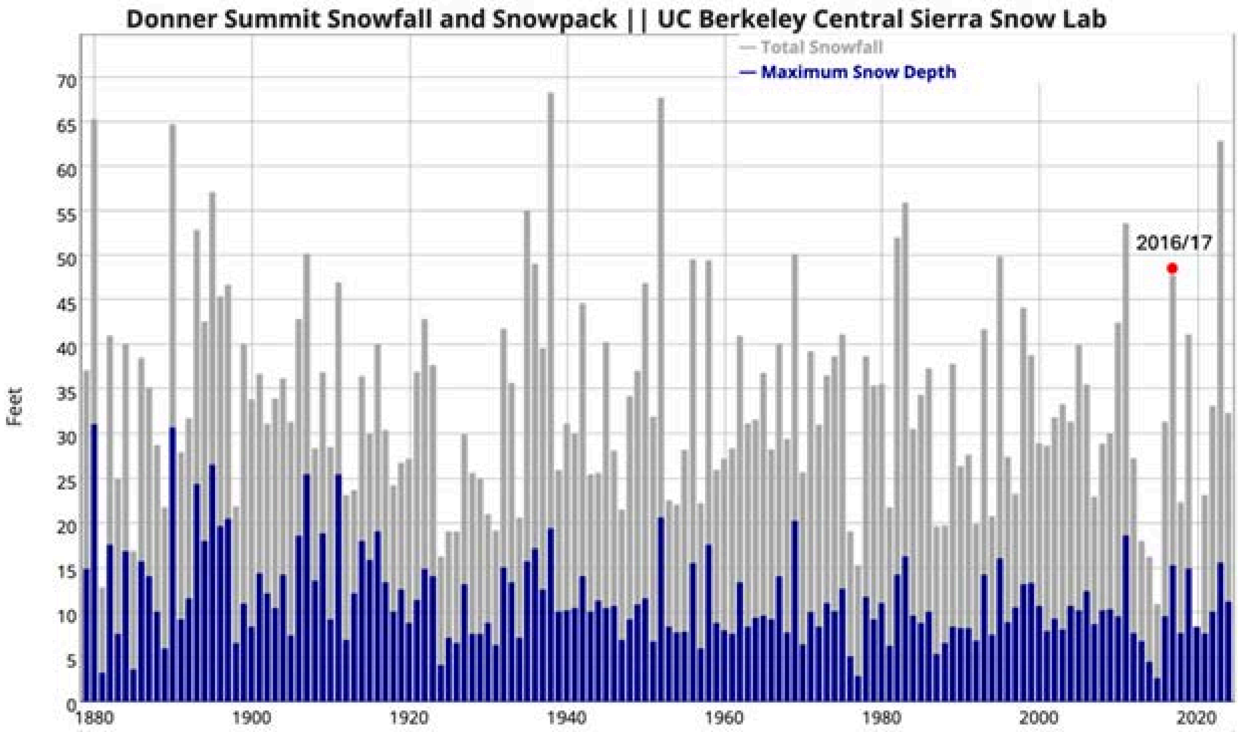


Figure 2. Total snowfall and maximum snow depth at Donner Pass, 187-2024. Source: UC Berkeley Central Sierra Snow Lab.

Across the western United States, the water stored in snowpack (also known as snow water equivalent, or SWE) has declined since mid-century, largely due to earlier snowmelt and rainfall during the spring melt season and additional declines in winter precipitation.

In a warming climate, California faces the possibility of low-to-no-snow futures becoming more common by the 2050s. Blockbuster winters like 2016/17 in the Sierra Nevada may become a distant memory. But the impacts on California go beyond outdoor recreation occurring in its mountains.

Mind the Water Gap

About 60% of the water used for agriculture, households, businesses and both natural and managed ecosystems in California is sourced from the Sierra.

When the amount of snow declines and timing of snowmelt shifts, a mismatch between water supply and demand in the communities downstream can occur – also known as a "water gap".

A recent study led by Dr. Areidy Beltran-Peña, a postdoc at Stanford University, investigated the future of the water gap for irrigation using a novel, scalable global climate model that can zoom in on the details of mountain ranges to better capture the response of snowpacks to a warming climate. Back in 2019, I had run this novel climate model using a high greenhouse gas emissions scenario out to 2100.

Dr. Beltran-Peña then compared the historical and modeled future snowfall, rainfall, and their contributions to irrigation water supply. Her research identified a significant shift in the Sierra Nevada from a snow-dominated

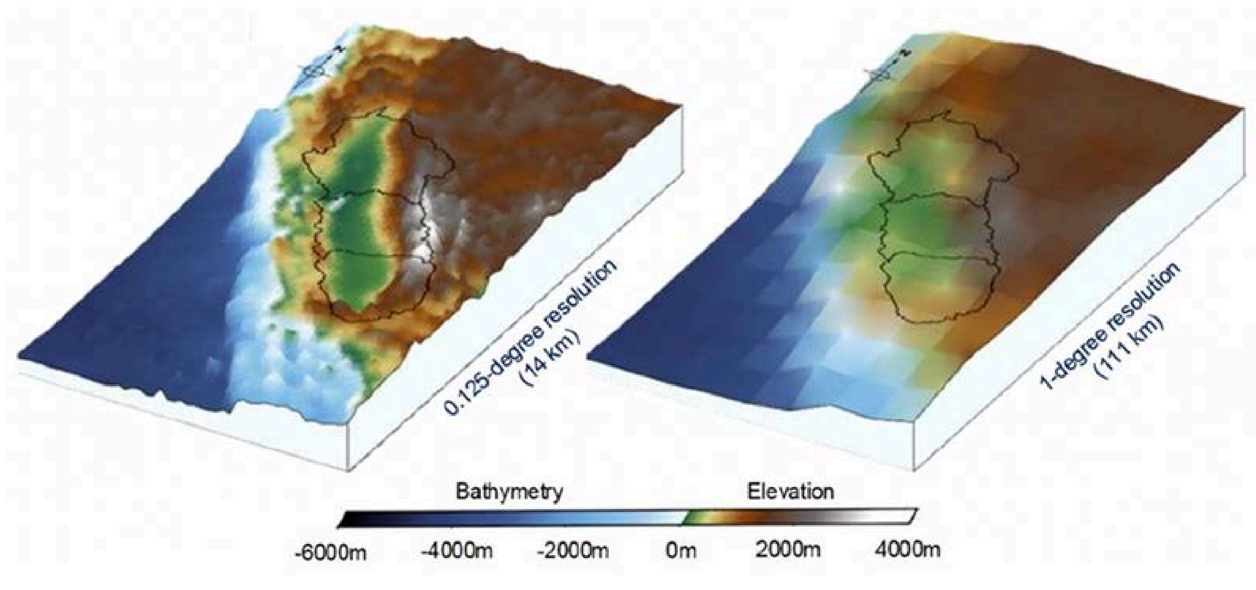


Figure 3. Detailed mountain topography (left) in the climate model used for Dr. Beltran-Peña's study better captures the seasonal accumulation and melt seasons in the Sierra Nevada compared to a standard global climate model with coarse mountain topography. Figure from Beltran-Peña et al. 2025.

mountain range to rain-dominated mountain range as the climate warmed. The warmer temperatures also contributed to an earlier melt season, advancing by about a month.

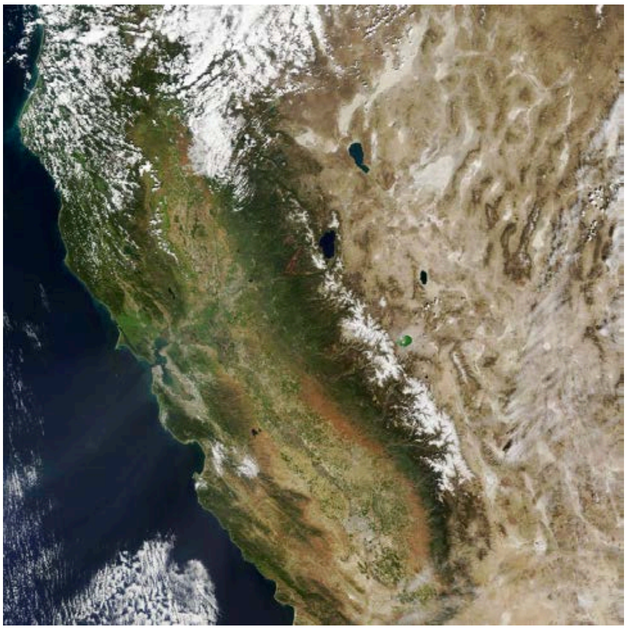


Figure 4. March 2015 snowpack extent for the Sierra Nevada mountain range. Based on tree-ring records of precipitation anomalies and of temperature, scientists found that the 2015 snowpack was the lowest ever recorded in the last 500 years (Belmecheri et al., 2016 in Nature). Imagery source: NASA Earth Observatory

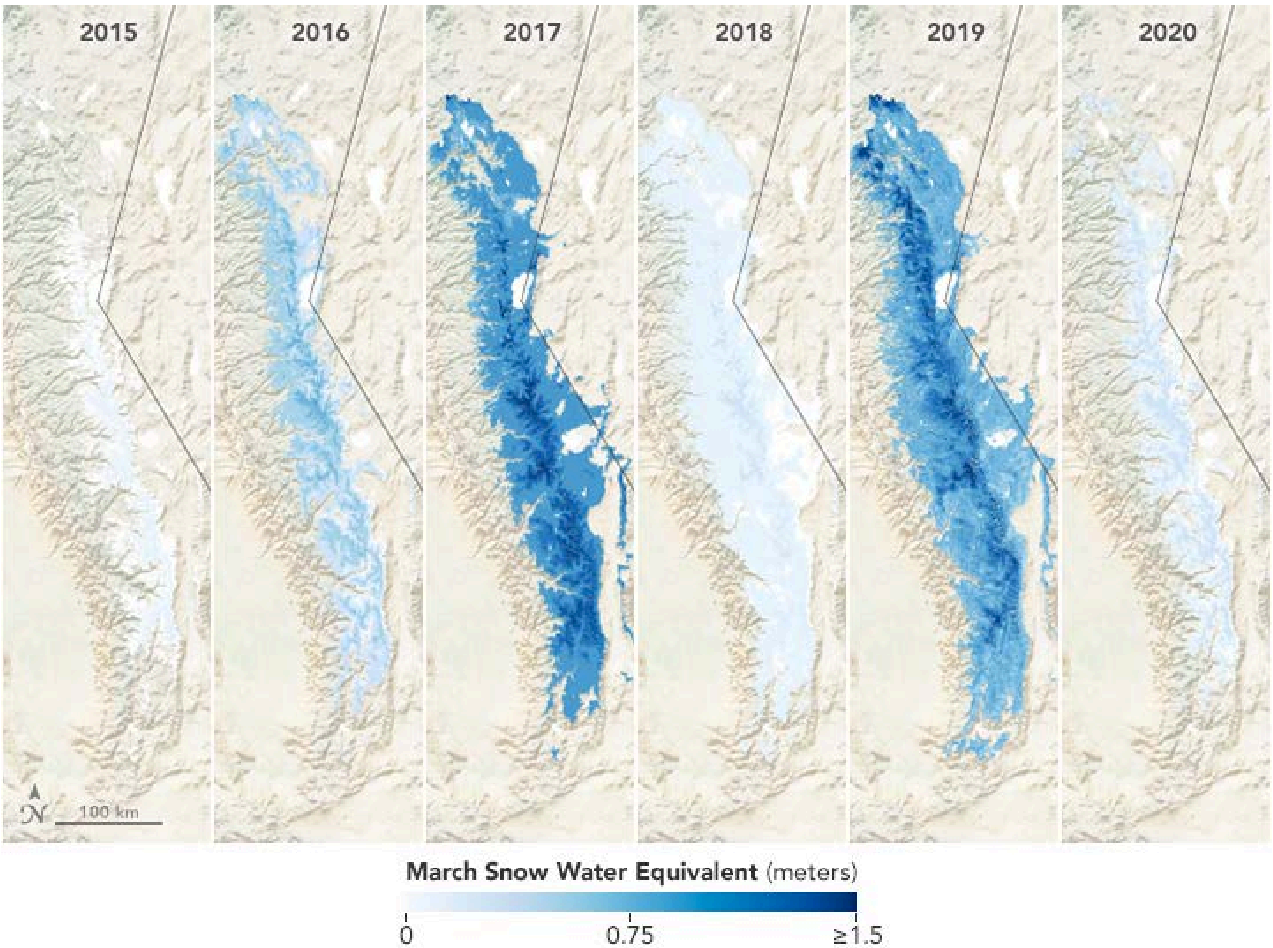


Figure 5. 2015-2020 March snow water equivalent in the Sierra Nevada. 2015 was the lowest snow year on record (2015) which was followed by an average snowpack (2016), and a very abundant one (2017). Source: Kathryn Hansen, NASA Earth Observatory

The shift in the timing and amount of water available from snowmelt and rainfall led to a widening water gap during the summer months, despite increases in rainfall. The issue is that snowmelt gradually (weeks to months) contributes to water supply as it melts, while rainfall is delivered more immediately (within days). The key to alleviating agricultural irrigation water gaps in a less snowy and rainier future is to improve effective storage strategies.

Dr. Beltran-Peña concludes her research paper with the following paragraph:

The name 'Sierra Nevada' translates to 'snow-covered mountain range' in Spanish. This mountain range was first labeled as the Sierra Nevada on a map in 1776 by Pedro Font. On April 3 of that year, coinciding with the date that has been used since the early 1900s to estimate peak SWE in the Western US, Font stood on a hill near the confluence of the Sacramento and San Joaquin Rivers and wrote, 'Looking eastward, we saw on the other side of the plain and about thirty leagues distant a great snow-covered mountain range, white from crest to foot' (Font 1776). Nearly 250 years later, with dramatic declines in snowfall and snowpack, the 'snow-covered' description implied by its name may become less fitting for the Sierra Nevada as the climate continues to warm. In tandem with a greater fraction of precipitation falling as rainfall over the mountain range, the Sierra Nevada may be transforming from a 'Sierra Nevada' into a 'Sierra Lluviosa'–a 'rainy mountain range.'

Tilly Jane, Mt. Hood

BY DAVE HILL

The CSO team is always happy to meet new participants on their 'home turf,' so to speak. We love getting out in the field to talk about snow and water resources, different types of snow data and what to do with it, and winter recreation! We were recently invited by the Friends of Tilly Jane Cabin to join their annual work party on Mt. Hood, Oregon and to share information about CSO and how to get involved.

The Tilly Jane A-Frame is an amazing historic cabin on the northeastern side of Mt. Hood that can be rented year-round. It was constructed in 1939 by the Civilian Conservation Corps. The cabin is a two(ish) hour hike from a sno-park and provides incredible access to the north side of Mt. Hood including the Cooper Spur climbing route, the Elliot Glacier, and more.

The Friends of Tilly Jane Cabins is an organization that helps to maintain the historic facility through regular work parties and an annual 'wood haul.' With a long winter season at that elevation on Mt. Hood, it takes an astonishing amount of wood to keep the renters warm.

Zach Butler, the newest member of the CSO science team will be traveling to Mt. Hood in October to meet the work party, shuttle a few (a lot) loads of wood, and to explain the how, what, and why of the CSO effort. The work party attracts a large and dedicated group of attendees, all of whom are outdoor enthusiasts interested in learning more about Mt. Hood and other Cascades mountains.

Mt. Hood is actually one of the domains that we model every single day, and you can find the results for Mt. Hood and our other domains at mountainsnow.org.

Figure 1. Heather and Tyler in the early morning light low on Cooper Spur on the north side of Mt. Hood.

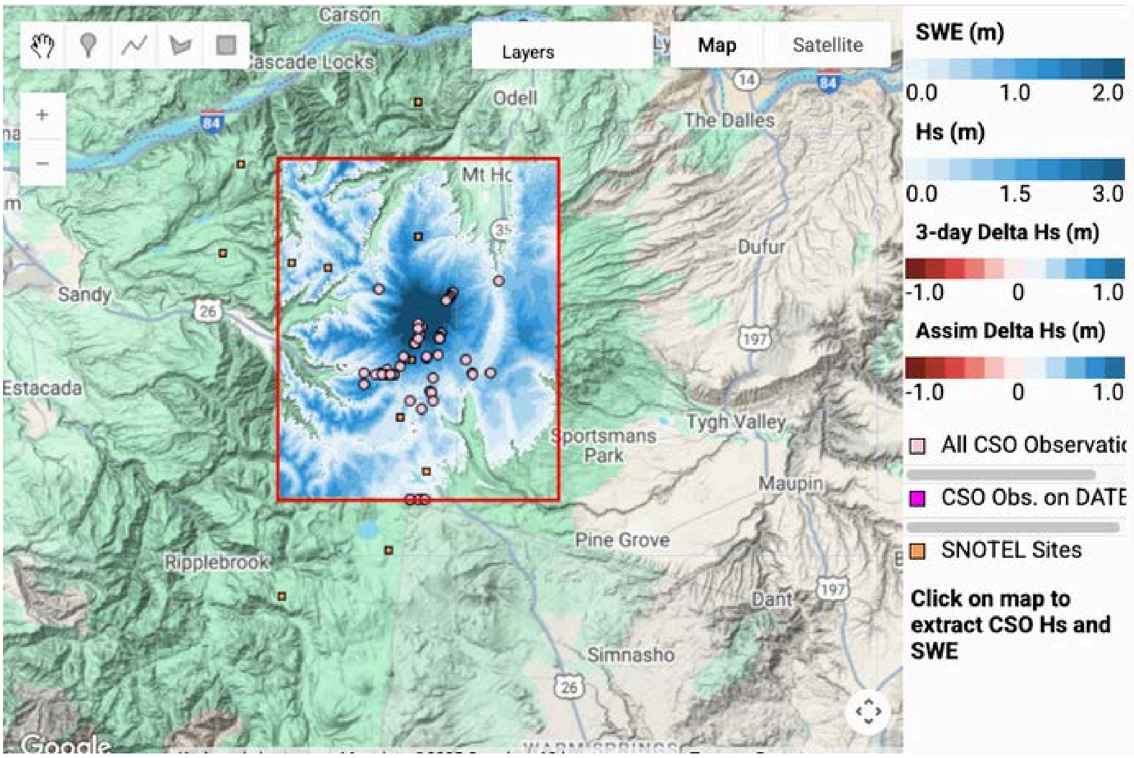


Figure 2. Mt Hood domain and existing snow observations.

SNOW & AVALANCHE WORKSHOPS

Greetings CSO participants! The days are getting short, the temps are cooling, and snow will fly before you know it! Which means it is Snow and Avalanche Workshop season! The many regional events across the country are some of the most fun and informative events you can go to. It is a cross-pollination between avalanche professionals and researchers, academic researchers, and, most importantly, members of the recreational community who spend much of their winter season out in the snow! The format, duration, and size of these events all vary, but if you live close to one of them, please be sure to consider attending. Fees are usually very modest and the funds typically help to support local and regional avalanche centers.
A complete listing of these events, with links to their individual web pages can be found at: https://www.americanavalancheassociation.org/events.

The CSO project will be busy at these events so if you run into any of us, please introduce yourselves and say hello. We'd love to meet you and hear about your experiences with CSO and your own winter adventures. In October, Gabe Wolken will be doing some outreach and marketing at the Colorado Snow and Avalanche Workshop in Breckenridge. All of the SAW events are amazing, but CSAW is near the front of the pack in terms of the quantity and quality of fascinating science going on out in the snow.

On the very same day, Dave Hill will be down in the Lake Tahoe area speaking at the California Snow and Avalanche Workshop, sponsored by the Sierra Avalanche Center. Dave will be focusing his presentation on the new U.S. Bureau of Reclamation project (see article on p. 3) since Lake Tahoe will be one of the target areas for that study.

CALIFORNIA AVALANCHE WORKSHOP

SIERRA AVALANCHE CENTER
In Partnership with the US Forest Service
SierraAvalancheCenter.org

CENTRAL OREGON
AVALANCHE CENTER

Finally, in November, Dave will be speaking at the Bend Snow and Avalanche Workshop. Hosted by the Central Oregon Avalanche Center, BendSAW is an up-and-comer event that has flourished thanks to the great Bend outdoor community and the fantastic venue at the Central Oregon Community College. Up north in Alaska, Katreen will be tabling a CSO booth at the Southcentral Alaska Avalanche Workshop. Come say hello!

Speaker lineups for all of these workshops are still being hammered out, but they typically include a good mix of snow science, climate, accident debriefs and lessons learned, psychology and decision making in avalanche terrain and more.

There's swag, snacks, and new friends to be made. Thanks again if you are able to make it to any of these events and show your support for the backcountry recreational and professional communities.

See you out there!

Over the years, we've been fortunate to share the snow with so many amazing people on the CSO team and in our community. Together, we've worked, played, and learned, always driven by a shared wonder for snow. Thank you for being part of this journey —we can't wait to see what discoveries we'll make together next!

-Dave, Katreen, Gabe & Zach (& Nina)