Mountain Views Chronicle

Volume 16 • 2022

Informing the Mountain Research Community

Cover Art: Three watercolor paintings of the North Cascades. Left: This piece was done below the small Iceworm Glacier on Mt. Daniel, in the Alpine Lakes Wilderness in August 2022. It looks out towards the prominent Cathedral Rock. Snow patches are far and few between. Top right: Sholes Glacier, on Mt. Baker, looking startlingly bare of snow in 2015. This glacier feeds the North Fork of the Nooksack. Note the small figure at the terminus - the photo that inspired this piece was taken from where the glacier ended 35 years prior. The tiny size of the human figure where it currently ends gives an indication of the major retreat over that time period. Bottom right: Easton Glacier, on Mt. Baker. The red line graph shows the distance the glacier has retreated from 2000-2021, which is about 350 m (~1,150 ft). Highlighted on the data line is 2011, a year of heavy snowfall that showed me a glimpse into winters of the past. Artist: Jill Pelto.

Table of Contents

From the Editors

Dec. 20, 2022

Dear Friends and Colleagues,

In many ways, the world we live in feels filled with extremes right now: unheard of drought, unprecedented warming, unparalleled rates of change. Dramatic conditions can be frightening, dangerous, or stressful, but they can also be exhilarating, inspiring, or even transformative.

This issue of the Mountain Views Chronicle seeks to highlight both sides of **research in the extreme.**

In this issue we share stories about science that either investigates extreme events or where the research itself is carried out in exceptional conditions: high, dry, cold, or remote.

Our *Feature Article*, from Laura Dye, considers how tree rings can open a window to the past to help researchers better understand how our current snow droughts compare to past paleodroughts.

Two *Brevia,* by Jill Pelto and Mauri Pelto and Jessica Lundquist, also consider snow, but from a different angle. Respectively, they cover rapid glacier decline in the North Cascades and tracking snow sublimation on a highly detailed scale.

All three of our *Field Notes* take us to high elevations. Two offer perspectives on conducting research on mining sites, from Maeve Wilder and Martha Apple. The third recounts an adventure Stu Weiss had one summer chasing butterflies for research.

Additionally, this issue shares evocative depictions of nature in poetry from Annie Barrett and Joe Glassy and paintings and photographs from Jill Pelto, Annie Barrett, Emilio Mateo, Valerie Cohen, and Joe Glassy.

As we move into the new year, we wish all of you a coming season of balance between the restfully mundane and the exciting extreme!

Sincerely,

Elise Osenga, *Editor in Chief*
Aspen Global Change Institute

Jeremy Littell, *Editor*
Alaska Climate Adaptation Science Center, USGS

Martha Apple, *Editor*
Montana Technological University

Tree Rings and Cascade Snow: Are Warm Snow Droughts a New Phenomenon?

Laura Dye
Natural Resource Specialist; Colorado River Commission of Nevada

The western US has experienced snow droughts of increasing duration and severity since the mid-20th century (Huning and AghaKouchak, 2020). The temperature-sensitive Cascade Range snowpacks in particular have experienced some of the largest observed declines (Mote et al., 2005). Recent research suggests 'warm' snow droughts, caused by winter precipitation falling as rain rather than snow, play a major role and may be unusual relative to past 'dry' snow droughts caused by a lack of winter precipitation (Mote, 2003; Sproles et al., 2013; Harpold et al., 2017; Lynn et al., 2020). Considering the recent 2014-2015 warm snow drought event, water supply managers seek to understand if warm snow droughts are unusual and if they are going to worsen. The new societal, economic, agricultural, and ecosystem impacts posed by warm snow droughts are a mounting challenge for water resource managers in the West.

My MS thesis research was aimed at using tree rings to reconstruct pre-instrumental snowpack in the Cascade Range, USA. This work is part of a larger western United States paleosnow research project under the supervision of Dr. Bethany Coulthard, in the Hydrology, Tree Rings, and Climate (HYTRAC) Lab at the University of Nevada, Las Vegas, and contributes to a growing widespread effort to develop and improve paleosnow records in the face of global snowpack declines.

Figure 1: *Laura Dye collecting a Western Juniper (Juniperus occidentalis) tree core sample at the Frederick Butte sample site in Oregon.*

Tree-ring chronologies provide precise, annually resolved, multi-century paleoclimate information which may enhance our knowledge of the natural long-term variability in the climate system, beyond the instrumental record (Fritts, 1971, 1976).

Mounted and surfaced Western Juniper (Juniperus occidentalis) tree core samples from the Frederick Butte, Oregon sample site. Image credit: author.

Dendroclimatology: using tree rings to study current climates and to reconstruct past climates.

In this work, I use two distinct types of tree-ring proxies, sensitive to total annual snowpack fluctuations, which may be recorded in annual radial growth increments (e.g., tree rings) in contrasting ways. Under specific environmental conditions, ring widths of some high-elevation tree species may be negatively correlated with snowpack (a low snowpack corresponds to a wide tree ring). These proxies are energy-limited in that deep snowpacks truncate the length of the growing season (Heikkinen, 1985; Peterson and Peterson, 1994, 2001; Peterson et al., 2002) and are sensitive to the 'functional snow depth' status at the beginning of the conifer growing season (Coulthard et al., 2021). Thus, it doesn't matter if the snowpack deficit was caused by rain (warm snow drought), or by a lack of winter precipitation (dry snow drought), this proxy *should* record both dry and warm snow droughts. Conversely, the ring widths of lower-elevation species may be positively correlated with snowpack (low snowpack corresponds to a narrow tree ring). These proxies are moisture-limited in that they primarily depend upon snowmelt-derived soil moisture for growth (Peterson and Peterson, 2001; Peterson et al., 2002; Coulthard et al., 2021). Therefore, this proxy *should* only record dry snow droughts as it may misdiagnose cool-season rain (warm snow drought) as snow. Importantly, these two distinct proxy types offer a potential opportunity to do what previous dendrohydrologic snowpack reconstructions could not: to distinguish between the very different warm versus dry snow drought processes of the past.

For my thesis research, I developed a novel dendroclimatological approach that pairs energy-limited and moisture-limited tree-ring chronologies to develop complimentary, independent snowpack reconstructions of warm and dry snow droughts for the Cascade Range, USA. By examining the two reconstructions in tandem, I quantified and compared the magnitudes and durations of warm versus dry snow droughts over the past 155 years, relative to the observed period of record (1952-2018). As a check to ensure that these two proxy types are recording snow droughts in the way in which I hypothesize, I utilized Hatchett et al.'s phase diagram approach (2022), using the Western Regional Climate Center's Snow Drought Tracker (WRCC, 2022). Drawing from select Natural Resource Conservation Service SNOTEL station's snow water equivalent (SWE) and precipitation datasets, the phase diagram displays cool-season conditions, relative to the station's period of record.

HYTRAC Lab MS student Inga Homfeld collecting a Mountain Hemlock (Tsuga mertensiana) tree core sample at the Mount Hood, Oregon sample site. Image Credit: Laura Dye.

In doing so, this tool aids in visualizing the evolution and type (warm vs. dry) of snow drought for a given water year in the observed record.

By pairing these reconstructions, I was able to successfully disentangle the warm vs. dry of snow drought. Preliminary results suggest that while more warm snow droughts have occurred in the pre-instrumental record, the magnitude of these events has intensified in recent decades, indicating that the observed period of record may not encompass the full range of Cascade Range snow drought variability. However, it is important to note that a degree of uncertainty remains as these records do not entirely capture the magnitude of observed snow drought events and thus, warrants future work.

Nonetheless, these individual warm and dry snow drought reconstructions provide a new long-term context for what the natural Cascade Range hydroclimate system is capable of, which may serve water resource managers and climate adaptation specialists to plan for intensifying warm snow drought risk over the following decades.

LITERATURE CITED

Coulthard, B. L., K.J. Anchukaitis, G.T. Pederson, E. Cook, J. Littell, and D.J. Smith. 2021. Snowpack signals in North American tree rings. Environ. Res. Lett., 16(3), 034037.

Fritts, H.C. 1971. Dendroclimatology and dendroecology. Quaternary Research, 1(4), 419-449.

Fritts, H.C. 1976. Tree rings and climate. New York: Academic Press.

Harpold, A. A., M. Dettinger, and S. Rajagopal. 2017. Defining snow drought and why it matters. Eos, 98.

Hatchett, B. J., Rhoades, A. M., & McEvoy, D. J. 2022. Monitoring the daily evolution and extent of snow drought. Natural Hazards and Earth System Sciences, 22(3), 869-890.

Heikkinen, O. 1985. Relationships between tree growth and climate in the subalpine Cascade Range of Washington, USA. The Finnish Botanical Publishing Board, Annales botanici fennici, 1-14.

Huning, L. S., and AghaKouchak, A. 2020. Global snow drought hot spots and characteristics. Proceedings of the National Academy of Sciences, 117(33), 19753-19759.

Lynn, E., A. Cuthbertson, M. He, J.P. Vasquez, M.L. Anderson, P. Coombe, J.T. Abatzoglou, and B.J. Hatchett. 2020. Precipitation-phase partitioning at landscape scales to regional scales. Hydrology and Earth System Sciences, 24(11), 5317-5328.

Mote, Philip W. 2003. Trends in snow water equivalent in the Pacific Northwest and their climatic causes. Geophysical Research Letters, 30(12).

Mote, P. W., Hamlet, A. F., Clark, M. P., and Lettenmaier, D. P. 2005. Declining mountain snowpack in western North America. Bulletin of the American meteorological Society, 86(1), 39-50.

Peterson, D. W., and D. L. Peterson. 1994. Effects of climate on radial growth of subalpine conifers in the North Cascade Mountains. Canadian Journal of Forest Research, 24(9), 1921-1932.

Peterson, D. W., and D. L. Peterson. 2001. Mountain hemlock growth responds to climatic variability at annual and decadal time scales. Ecology, 82(12), 3330-3345.

Peterson, D. W., D.L. Peterson, and G.J. Ettl. 2002. Growth responses of subalpine fir to climatic variability in the Pacific Northwest. Canadian Journal of Forest Research, 32(9), 1503-1517.

Sproles, E. A., A.W. Nolin, K. Rittger, and T.H. Painter. 2013. Climate change impacts on maritime mountain snowpack in the Oregon Cascades. Hydrology and Earth System Sciences, 17(7), 2581-2597.

Western Regional Climate Center, Desert Research Institute, 2022, Western regional climate center snow drought tracker: https://wrcc.dri.edu/my/climate/snow-drought-tracker

Heat Waves' Impact on Glaciers and Alpine Watersheds:

A narrative of long-term research North Cascade Glacier Climate Project

Jill Pelto
Art Director NCGCP; Artist; Science Communicator (jillpelto.com)

Dr. Mauri Pelto
Science Director NCGCP; Glaciologist; Associate Provost and Special Assistant to the President at Nichols College (glaciers.nichols.edu)

(This article is associated with the cover art of this issue: "Three watercolor paintings of the North Cascades" by Jill Pelto.)

For 39 years (and counting), we have conducted long term fieldwork across a group of mountain glaciers in Washington state. This research quantifies the specific impact of heat waves on glaciers and the mitigating impact on the rivers they feed. We use data, art, and images to chronicle and communicate the long-term impact of climate change on the glaciers, including the volume reduction (by ~1% per/year this century) and the consequent reduction in summer runoff to glacier fed rivers such as the Nooksack.

Around our Mount Daniel base camp are a dozen shallow ponds, 10-20 cm depth on average that typically last until tadpoles hatch in late August or early September, but they dried out in 2021. The primary inhabitants are frogs (Rana cascadea) and their tadpoles. In 2022 despite a wet spring and early summer that filled the ponds (above, right) no tadpoles were observed, where typically there are several hundred. Image Credit: Jill Pelto and Mauri Pelto.

In 2021 below Easton Glacier we noted many alpine plants that had emerged just before or during the record June heat wave that were desiccated/cooked by the heat in this area of relatively barren volcanic rock, most notably lupine. This year in the same region we noted that ~30% of the lupine had failed to develop by August 2022, despite a cool wet spring. In contrast the evergreen alpine plants in the same area penstemon, saxifrage, pink and white heather, and partridge-foot were fine. Image Credit: Jill Pelto and Mauri Pelto.

The North Cascade Glacier Climate Project that we direct has for 39 years observed the response of North Cascade glaciers to climate change. In the last several years an increasing number of heat waves have affected alpine glacier regions in the Pacific Northwest, illustrating that heat waves and alpine glaciers are incompatible. The most extreme heat event in the Pacific Northwest occurred in late June 2021, setting all-time records across the region (Thompson et al, 2022). The heat wave and ensuing warmth stripped the snow cover from glaciers right to the summit on the highest mountains, from Mount Shasta, California to Mount Baker, Washington — all by mid- August.

Sholes Glacier and stream gage station. We have constructed a rating curve for this station that the Nooksack Indian Tribe maintains (Grah and Beaulieu, 2013). This photo was taken below Sholes Glacier in 2015 and exhibits the darkening of the surface that occurs in high melt years, increasing melt rates. Image Credit: Jill Pelto and Mauri Pelto.

This exposed the dirtier ice that lies underneath the snow and melts more rapidly than snow under the same weather conditions. The resulting higher melt rate led to increased discharge in glacier fed streams, while non-glacier fed streams in the region had significant declines in discharge.

One key aspect of the shifting climate is more frequent and more intense heat waves. Using daily maximum temperatures for the 1981-2021 period for Mount Baker from ERA5 temperature reanalysis indicates 83 days where the maximum temperature exceeded 12°C for 2 days per year. In the last six years, 32 days exceeded 12°C, an average of over 5 days per year. We have observed this effect on the glaciers closely during our field work and felt this warmth as we backpacked to our field sites.

Runoff downstream in Wells Creek and the North Fork Nooksack River (NFN) is changing in part because of altered glacier runoff. Glacier runoff is a major source of streamflow during the summer low-flow season, mitigating both low-flow and high water temperatures (Pelto et al, 2022). The primary response to these summer heat waves is increased discharge in the heavily glaciated NFN and increased stream temperature in the unglaciated South Fork Nooksack (SFN).

Discharge rose at least 10% in 20 of the 24 events in the NFN with an average increase of 24%. In the SFN all 24 events led to a decreased discharge with an average decrease of 20% (Pelto et al, 2022). For water temperature, the mean increase was 0.7 °C (±0.4 °C) in the NFN and 2.1 °C (±1.2 °C) in the SFN. During the June 2021 heatwave from June 21-29, maximum daily stream temperature in SFN warmed 3°C, compared to 0.8°C for NFN. North Cascade glacier response to climate change has been a 25-30% volume loss from 1984-2022. During 24 heat waves in the region from 2009-2021, mean daily ablation during the heat waves ranged from 4.5-7.2 cm water equivalent per day. The highest rate of 7.2 cm per day was during the June 26-July 1, 2021 period. The ice and firn for the same weather conditions have a 30-40% higher melt rate than the snowpack. (Firn is the intermediate between snow and ice, forming after the metamorphosis of snow through an entire melt season.) An early season heat wave strips the snow off earlier, exposing the darker, faster melting glacier surfaces for longer, further increasing mass loss.

These findings are the result of this unique long-term study, which illustrates how much North Cascade glaciers are declining and why this decline is important to understand. As detailed above, glaciers are a vital resource for rivers, ecosystems, and people. The water they supply through runoff supplements dry, hot summers, filling drinking water reservoirs and fueling hydropower. Without their addition, glacially-fed rivers would be low and warm in the summer, greatly affecting the alpine environment from low-lying wetlands to high rocky outcrops, and impacting the plants and animals that live across all of those elevations. It is clear in our research that glaciers in the North Cascades are a crucial ecosystem puzzle piece. We hope our work will help expose broad audiences to this critical role and that by chronicling their impact we can encourage glacier protection. Climate change is increasing, but so too is our goal with the North Cascade Glacier Climate Project (NGCP) to be a part of communicating its effects across this incredible part of our world.

More information in the NGCP can be found at: https://glaciers.nichols.edu/

LITERATURE CITED

Grah, O., Beaulieu, J. 2013. The effect of climate change on glacier ablation and baseflow support in the Nooksack River basin and implications on Pacific salmonid species protection and recovery. Climate Change and Indigenous Peoples in the United States, 120, 657-670.

Pelto, M.S., Dryak, M., Pelto, J., Matthews, T., Perry, L.B. 2022. Contribution of Glacier Runoff during Heat Waves in the Nooksack River Basin USA. Water, 14, 1145. https://doi.org/10.3390/w14071145

Thompson, V., Kennedy-Asser, A., Vosper, E., Lo, E., Huntingford, C., Andrews, O., Collins, M., Hegerl, G. and Mitchell, D. 2022. The 2021 western North America heatwave among the most extreme events ever recorded globally. Science Advances, 8(18). DOI:10.1126/sciadv.abm6860

Poetry

Frogs

It’s a wonder that I don’t trip,

always walking around looking up at the sky.

Cumulous, thunderhead, bendable
lenticulars waving along the Sierra Crest.

Did you know that frogs apparently can see
if there’s another lake over the rise

by looking up at the sky? Something about
atmospheric reflection

and the aptitude for seeing.

How this is known by man, I am not clear –

Can one ask a frog?

Nonetheless, I believe it

and continue to watch the sky.

Annie Barrett
11.27.2018

An Extreme Number of Sensors in One Spot

Jessica Lundquist
University of Washington

With thanks to Eli Schwat, University of Washington, for editorial help.

Did you ever return home from fieldwork and think to yourself: did I hang that temperature sensor the right height above the ground? Am I measuring the wind in the best location? Did I just accidentally bias my entire study because I have no idea how representative my measurements are of the 20 m cube I'm standing in, let alone the whole valley?

These questions have long kept me up at night. Meanwhile, Julie Vano (at the Aspen Global Change Institute) stays up at night worrying about water in the Colorado River, a topic that should keep you up at night too. In recent years, streamflow has been less than one would expect given the snow measurements used for forecasts. Since approximately 70% of Colorado river streamflow originates as snowmelt, a difference between expected and received water from snow matters greatly to water managers and water users. But why the discrepancy? Ethan Gutmann (NCAR) stares out his window and wonders if maybe the snow blew away. All three of us are collectively wondering - what is happening to the water now, and what should we expect in the future?

Blowing snow can increase the amount of snow lost to the atmosphere, which can change the water available for runoff, but how do we measure it? Working together, Julie, Ethan, and I put out an SOS to the National Science Foundation that we needed help. SOS isn't just a distress signal: it's an acronym for Sublimation of Snow, the process by which ice within the snow matrix turns into water vapor and is potentially blown away to another watershed. Sublimation is extremely tricky to measure. Rebecca Mott (SLF, Switzerland) reviewed studies on sublimation from across the globe and found values reporting losses ranging anywhere from 10% to 90% of snowfall (Mott et al., 2018). While some of this variability can be attributed to location at which snow measurements are taken (we expect to lose more snow to sublimation in places that are dry and windy, like Colorado, and less in places that are moist and wet, like western Washington) we still see wide variation between different methods used to estimate sublimation at a given spot.

The solution to the sublimation challenge: "Let's try to put every type of measurement

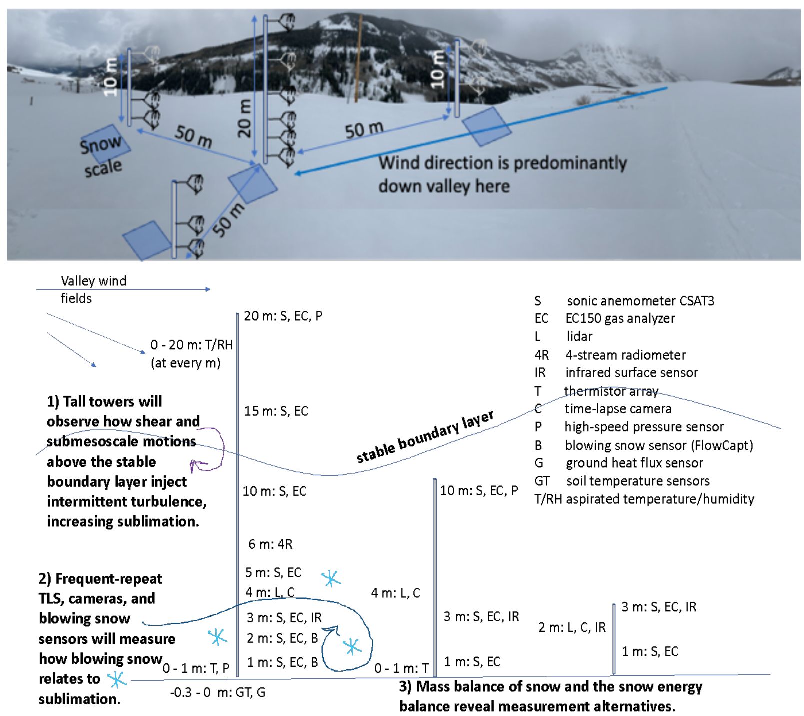

Figure 1. Sketches from proposal asking for every way to measure sublimation that I could think of.

we can think of together in one spot and compare them very carefully (Fig. 1)!"

Ideally, we wanted to arrange them in a "control triangular prism" and try to track every snowflake inside that control volume. Ideally, we wanted to deploy these instruments in a valley where the Department of Energy (DOE, SAIL https://sail.lbl.gov/about/) and the National Oceanographic and Atmospheric Administration (NOAA, SPLASH, https://psl.noaa.gov/splash/) were already intensely measuring weather at the valley scale at the valley scale and where the Rocky Mountain Biological Laboratory (RMBL) has been conducting ecology-related research for over 50 years.

To our great delight and excitement, our proposal was selected after rigorous NSF review, and NCAR's Earth Observing Laboratory (EOL) designated the community instruments of their Integrated Surface Flux System (ISFS) to come together in our envisioned triangle to study sublimation. Their team of scientists and engineers, led by Steve Oncley, had the expertise to turn my sketches into reality (Fig. 2, Fig. 3). From across University of Washington, UCAR, and the Aspen Global Change Institute, we assembled a team of our own. The sensors were deployed, as hoped, near RMBL in October 2022. Shortly thereafter snow fell, and now we're ready, at least to the best of our ability, to track that snow's fate, using an extreme number of sensors, all basically in one spot. With the support of our experienced team, we can now begin to explore what happens to snow in near real time, and we can continue to wonder, and maybe even begin to answer, what should we expect in the future?

To learn more about the SOS project, visit: https://www.eol.ucar.edu/field_projects/sos

To view near real-time data visit: http://datavis.eol.ucar.edu/ncharts/projects/SOS/noqc_geo

LITERATURE CITED

Mott, R., Vionnet, V., & Grünewald, T. 2018. The seasonal snow cover dynamics: Review on wind-driven coupling processes. *Frontiers in Earth Science, 6*(197).

Figure 2. Looking up at the 20 m tower during October field deployment. On left, temperature and relative humidity sensors every 1 m, sonic anemometers (to measure aid movement) at every 4 m. Image Credit: Emilio Mateo, AGCI.

Figure 3. One of the 10 m towers with snow on the ground, Oct. 30, 2022. Image Credit: Isabel Suhr, NCAR.

Artwork: Photograph

An Extensive Installation

From October 1st-15th, a team of scientists from the National Center for Atmospheric Research, University of Washington, and Aspen Global Change Institute deployed an extensive array of near-surface atmospheric instrumentation in Gothic, Colorado. This project involves extremely dense instrumentation for near-surface atmospheric measurements to quantify the physical processes involved in snow sublimation. To endure the harsh winter in this area of the Rocky Mountains, this instrumentation will be tended to throughout the winter by members of the team staying in Gothic to ensure that all measurements are repeatedly gathered. Together the instrumentation is designed to quantify sublimation of snow during the winter months. This image shows the research team beginning to install a snow pillow, an instrument that measures the total water equivalent of the snowpack sitting above it, while our outreach team gathers audio and visuals for future educational materials. The tower in the back left is one of four installed during this deployment which allows for a gradient of measurements between 0-20 m above the ground.

About the Artist

The photographer, Emilio Mateo, is a Climate Science Fellow at Aspen Global Change Institute and is working to display this research on the sublimation of snow in the Colorado Rocky Mountains to a broader audience through photography, outreach videos, and educational materials.

12,000ft Science

The Epic of Burrows Basin, Silverton, CO

Maeve Wilder
Fort Lewis College

With thanks to the other research team members: Brooke Grover, Ben Violett, Gwen Benally, and, especially Anna Burdick for her work editing this article.

The sunny fall weather of late October may seem benign when you're staring longingly out the window during classes at 6,512 ft, but spend a night at 11,000 ft and it quickly becomes apparent that there is a whole other world juxtaposed above our heads in the mountain tundra. We wake up to frost on the inside of car windows and realize that the sun will not reach the bottom of the basin to warm us up before camp must be broken. Some of us had a rough two nights: we'd assumed it wasn't quite time for that 0°F degree sleeping bag and were incorrect. But shake that off - we have work to do. One bumpy experience later, up the narrow and winding road, we emerge out to the top of the mountain basin.

This really is a whole new world; tumbling hillslopes of golden grasses, wetlands of spongy moss, slopes of tumbled talus below dizzying peaks, burbling streams flowing with algae reminiscent of…maybe water nymph hair? It is mesmerizing to watch. There are rocks bristling with quartz crystals and hefty crickets that seem unafraid of our presence. Elk trails contour the landscape and the "squee" of pika prick the air frequently. The occasional crow has far too much fun soaring over their domain and laughing at our ground-bound human forms

The landscape we are working in. Image Credit: Anna Burdick.

below. This land is beautiful in a way that will catch you off guard even more than the cold does. There is ugliness too, though: the unfortunate pocking of old mines that occur with shocking frequency in this otherwise idyllic scene.

> "This land is beautiful in a way that will catch you off guard even more than the cold does.. "

There are five of us on this valiant scientific expedition, all environmental science students of Fort Lewis College. We designed and are in the thick of a project in Burrows Basin near Silverton, Colorado, with the guidance of Dr. Heidi Steltzer, a professor at Fort Lewis College (FLC). We are looking at the impacts of decades of mining in the highlands of the San Juan Mountains. This area is the birthplace of the snowmelt that feeds water supplies across the Southwest. Our goal is to understand the ecological state of this basin and that of nearby Stoney Pass by collecting data on water quality, soil content, and vegetation above, at, and below mine level. We are also mapping as many mines and tailing piles as we can find in the area. This turned out to be quite a lot of mines indeed!

At the top of Burrows Basin, shivers and grumpiness are melted away by the golden morning light as we shed layers and don backpacks heavy with gear. They will be heavier still as the day goes and we fill them with samples of soil and water.

It is a delicate yet hardy ecosystem we are studying. The alpine tundra is a place of strong winds and little rain, covered by snow for many months of the year. Plants that exist here eke out a living by sticking close to the ground and developing radical tap root systems. The life we can see is a fraction of the life that is here. Anything that grows does so slowly, saving up energy for the spectacular bursts of wildflowers that they will deploy in the spring, summer, and sometimes fall. This means that a disturbance to the landscape can have more severe, long-lasting effects than it would in, say, a lower elevation alpine forest. The mines in this basin are below the EPA's standards for remediation, but with this alpine life already tenuous in the face of climate change, we want to know if the effects really are negligible.

We counted almost 70 mine sites in a basin less than 1.5 square miles in area. In some places, tailing piles overlap each other creating great scars in their journey down the mountainside. Tailings piles are like big, tan meals that sit wrong in the stomach; gobbled up inner earth vomited on the surface of the land. They consist of sand and chunks of rock left over from the search for valuables. The minerals in them, which release slowly while underground, release much faster on the surface, leading to concentrations that can be toxic to the surrounding life and the humans that drink

Taking soil samples outside a mine. Image Credit: Gwen Benally.

the water far downstream. Many types of heavy metals, such as lead and arsenic, were also exposed from their 30-million-year residence deep underground, something the environment above may not be adapted to.

We hike, take samples, mark mine sites, and repeat. A few of the mine entrances are inaccessible due to snow covering the steep talus fields above which they sit. It is incredible to speculate on how those gold hunters lugged their heavy equipment on the backs of their noble burrows up the sides of mountains in order to dig in at such extreme angles. Gold lust gives extra-human determination maybe? We are the determined ones now, armed with pH probes and ziplock bags instead of pickaxes.

We work from the top of the valley down, taking measurements and samples above, at, and below mine sites, covering the tops and sides of mountains down to the wetlands at their bases. We use probes to take water quality parameters from the creek running through the basin as well as in the various

Recording observations of Burrows Basin. Image Credit: Anna Burdick.

pools dotting the wetlands at the bottom of the basin. Dissolved oxygen, pH, temperature, and mercury content are noted, and a water sample is taken from each site. These samples will be sent off to a lab for analysis. Soils are also collected in bags to be analyzed for heavy metal content. Vegetation greenness is assessed on site by measuring the light wavelength reflection of any given patch.

We find a broken 30 meter tape from some other field team of the past, an ancient rusty burrow shoe, and an abundance of sparkly rocks boasting large quartz crystals. We watch the crickets in the grass and marvel at their wings, useless for flying in the high wind, that have been modified to serve better as instruments with which to pierce through the said wind with sound and make their presence known. Some of the ponds we come across seem dipped right from the fae realm with their soft, spongey banks and crystalline waters. The tracks of coyote and elk in the shallows only further the sense of unseen presences moving with us. We stop to eat peanut butter and jelly sandwiches and enjoy a moment out from under our packs as the sun warms our faces.

By the end of the two days we are tired but feeling very accomplished. We have quite an amount of labeled bags of soil, bottles of water, and data to take back with us. We wish we could spend every last bit of our research time up here with the pika and the huge blue sky, but, alas, school and lab work beckon us insistently back. We will be processing soils and sending waters off to be analyzed in the coming weeks and hoping therein for a peek into how our new friend, the alpine tundra, is fairing. Fingers crossed we find nothing at all noteworthy, just conditions that nurture happy life. That doesn't often seem to be the way things go though, does it? Ah if only we humans were a bit less restless.

The Extreme Mountain Environment of the Badger Mine in Butte, Montana

Martha Apple
Professor of Biological Sciences, Montana Technological University

With: The Montana Tech Badger Mine Research Group: Robert Pal, Associate Professor of Biological Sciences Director of Restoration Ecology; Joe Griffin, Faculty Affiliate in Hydrology; Nicholas Rassheart, Graduate Student; Keith Moore and Daniel Kelly, Undergraduate Students; and others.

November 1st, 2022

As I hiked across the eerie landscape of the Badger Mine site in what would be the montane zone above Butte, Montana (1,901 m (6,237 ft) at 46.03 °N and -112.52°W, I realized that I was indeed in an extreme mountain research environment. The Badger Mine produced lead, zinc, silver, and copper in the early 1900s, but when underground mining shifted to open pit mining in the mid-1900s, the Badger Mine site became a place for the overburden, which is the overlying rock and soil of a mineral deposit. Until the 1970s, overburden was deposited truckload by truckload above the normal ground level, which resulted in an otherwise flat landscape with evenly spaced two-meter-tall mounds. Imagine, if you will, a flat version of a mogul ski field and you will get the picture, except that the mounds are in earth tones of surreal bisque, ochre, and russet.

Some plants have colonized the Badger Mine site. Our research group went to the Badger Mine site in October 2022 to explore questions of how the colonizing plants are able to survive in what are likely high concentrations of heavy metals in the soil, and if so, whether soil moisture, temperature, and pH influence the locations of the colonizing plants. These plants include volunteer *Picea engelmannii* (Spruce), *Pseudotsuga menziesii* (Douglas fir), *Juniperus communis* (Common Juniper), *Pinus contorta* (Lodgepole Pine), *Populus tremuloides* (Aspen), and *Sorbus aucuparia* (Mountain Ash) trees. In the swales between the mounds there are pockets of herbaceous plants with moss and a greenish biofilm/biocrust layer of what turned out to be a species of the metal-tolerant green alga, *Klebsormidium*.

At the Badger Mine site, we installed an array of soil temperature and moisture sensors at the tops of the mounds and in the swales concurrently with collections of soil samples for measurements of pH and metal concentrations, which will be measured with a handheld XRF analyzer. We anticipate collecting *in-situ* sensor data and mapping plants in spring 2023. These data will be used to investigate the influences of environmental conditions and metal content on colonization by pioneer plants of a mining-impacted area in the mountain west.

Montana Technological University Restoration Ecology Students installing soil moisture sensors at the Badger Mine waste site north of Butte, Montana (above). Badger Mine Site where volunteer trees are starting to populate the abandoned Badger Mine waste site (below). Image Credit: Martha Apple.

Artwork: Paintings

"Cool things happen when one combines art with science. It helps one to observe, wonder, ask questions and seek answers about and for this grand natural world."

-Annie Barrett

Stately Bristlecone

This tree grows on a dolomite dome, at around 11,000 ft, south of the Patriarch Grove in the White Mountains. It faces south, thus has been brutalized by storms over the centuries. All its bark is missing from that side, so the tree bled gallons of its dark sap to heal the wound, like a glass shield.

About the Artist

Valerie Cohen is a nationally-known watercolor painter and illustrator for books, including ones about high-altitude conifers. Her work and life story can be found at valeriepcohen.com

You and Me (Monarch Butterfly

In this painting, extreme relates to the need for protection as butterfly numbers plummet. This painting also represents the relationship between the Monarch, the milkweed, and the connection of the earth with humans.

About the Artist

Annie Barrett is an outdoor educator and coordinator of the citizen science National Phenology Network group through Valentine Eastern Sierra Reserves (VESR). She works closely with various science researchers at VESR, and (as a teacher, artist, naturalist, and employee) assists researchers of botany, mountain yellow legged frog, forest and fire ecology, and aquatic invertebrates. Annie enjoys combining science with art in her teaching and in her paintings.

Field Note

Extreme Butterfly Chasing

Stu Weiss

Stu Weiss is an independent conservation ecologist at Creekside Science and works with species ranging from Bay checkerspot and monarch butterflies to Bristlecone Pines with a special emphasis on topoclimate and microclimate.

The all-black butterfly popped up from among the rocks, a tantalizing half meter beyond the reach of my net. Trying to close the gap, I gingerly planted one foot on what looked like a solid large rock and took a swing and a miss but sent a rockslide hundreds of meters down the barren talus slopes, as I fell on all fours to avoid the same fate. A pika "eep-eeped" at me, either mocking my clumsiness or saluting my survival instinct (or both). As I caught my breath in the 3,500 m (11,500 ft) thin alpine air, I watched and heard the rocks plunge, bounce, and eventually skid to a halt 300 m below. Better them than me!

The year was 1979. What the hell was I doing risking life and limb up here at the headwaters of Cement Creek on the Western Slope of the Colorado Rockies? The four of us were after *Erebia magdalena*, the elusive all black butterflies found only above 3,000 m on near-barren talus, its larvae feeding on small tufts of grass among the scree. I had landed a dream summer job for a freshman – chasing checkerspot butterflies for Paul Ehrlich and his grad student Cheri Holdren at the Rocky Mountain Biological Lab. On our day off, we wanted to capture some *magdalenas* as evidence of our prowess in the art of butterfly chasing. The week before, we had sunk the lab International Scout field truck into a mud pit on the long approach track and had to get winched out. We fessed up to Paul when he saw the mud-caked 4WD truck, and he jokingly fired us on the spot. Today, seeking redemption, we maneuvered around the morass, parked where the road vanished into a late season snowdrift, and hiked 500 steep vertical meters up to this ridgeline perch. Taking in the glorious view spread around us, we got to work.

The *magdalena* were flying, but actually chasing after them was treacherous, to say the least. I found a somewhat stable set of small boulders and waited for them to come to me. Classic hill-topping behavior in butterfly-speak. None came within reach of my net. Frustration was building, as were the thunderstorm clouds that would halt any flight and invariably drive us off the mountain. One last shaft of sunlight shone through for a few minutes, my quarry arose, and I made my move and set off the rockslide. Done for the day.

As we hiked and talus-skidded back to the car, we learned that Craig, Cheri's young son, had nabbed ten *Erebia magdalena* while the rest of us were skunked. Score ten for pre-teen fearlessness and agility. After executing a 13-point turn in the Scout, we returned to the lab. Craig spread and skillfully pinned his trophies, and a few days later proudly presented them to Paul in a small museum case. The remainder of the summer, Craig and Paul never let us forget it.

" The all-black butterfly popped up from among the rocks, a tantalizing half meter beyond the reach of my net... "

Poetry

The Ice Watchers

Even the arctic wind today
lacks that expected conviction, arriving ok
but tardy by a day
on the weatherwoman's telling
shuffling into town
overcoated old men and women
move slow rote along creekside trails:
the ice watchers

gathering on log's lee, eddy'd out
in the waning circle
of water still left liquid
enough for one raft of ducks,
bubbles slide-like-knives under new crust
giving up to stillness
giving up

and what about that arctic?
It's somehow changed.
Thin Chukchi meltwater films atop thinner
 snow,
Two polar bears lounge oddly in lens or
 video,
abandoned, like the Kolychin Island weather
 hut
watching ice wane is not enough,
knowing only what Maritimus parents
 taught:
adapt, go on.

Sandy lies prone on old ice
blocked up at Prudhoe.
Perhaps back from Churchill, I learn
from her letter on time worn paper
damp-drying on the radiator,
binocular notched hours on nose,
Ursus ice-watching polar pups and mother

shuffling under more favorable climes,
now the ink is barely moving, scratched out
under arch of gray steel quonset
'will-be-back-in-spring', folded back,
put away, next to another
lens that needs cleaning,
back of closet.

Joe Glassy

Artwork: Painting

Rim Fire

This artwork was painted during the Rim Fire in the Sierra Nevada of California, with ash being caught into the oil paint, on the extremes of wildfire. Artist: Annie Barrett.

News and Events

CIRMOUNT Leadership

CIRMOUNT is in the process of restructuring. The current movement is to create a leadership team to help manage the listserv, re-establish an active website for the group, organize the biannual MtClim Conference and other gatherings, and publish this newsletter.

If you would like to join the conversation, please email eliseo@agci.org and **SAVE THE DATE** for a zoom meeting on **Jan. 12th** at **5pm Mountain Time,**

JOIN THE TEAM

Does seeing the MVC in your inbox fill you with joy? Are you fascinated by the latest stories from the field?

Consider joining our Mountain Views Chronicle editorial team! We are very much in need of help for soliciting, writing, and editing articles! Inquiries should be sent to: MtclimMVC@gmail.com

Call for Submissions:

The next issue of the Mountain Views Chronicle will run in December of 2023. Our theme will be A Growing World. This includes reporting research on plants, animals, human populations, even sediment layers—anything that grows over time!
The Mountain Views Chronicle accepts submissions of articles, field notes, artwork, and poetry. Please send all inquiries to MtClimMVC@gmail.com

.

Back Cover Art: The Ice Watchers—Montana. Photograph taken on 11/2/2022 from the Greenough Park (Missoula, Montana), north end bridge. Artist: Joe Glassy