

MOUNTAIN VIEWS

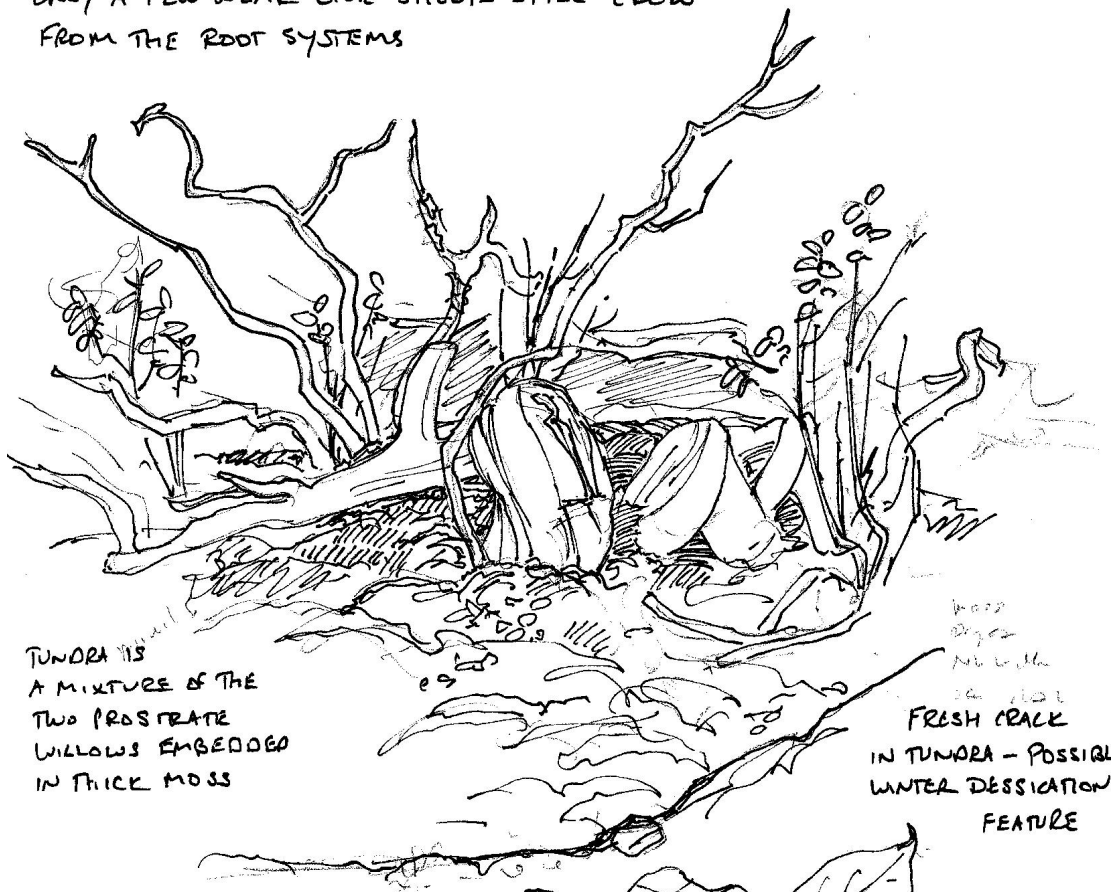
**The Newsletter of the Consortium for Integrated
Climate Research in Western Mountains
CIRMOUNT**



Informing the Mountain Research Community

**Vol. 5, No. 1
Winter 2011**

ONE OF MANY OLD BARELY ALIVE WILLOW HULKS. ONCE VIBOROUS
WILLOW TREES NOW REDUCED TO PILES OF BLEACHING BONES. NOW
ONLY A FEW WEAK LIVE SHOOTS STILL GROW
FROM THE ROOT SYSTEMS



AUGUST 24, 2010
HIGH AND DRY OLD TERRACE
ALONG THE SMALL STREAM BY
OUR CAMP.

FELT-LEAF WILLOW WITH
ITS THICK AND FELT-TEXTURED
LEAVES AND DISTINCTIVE
BULBS AT BASE OF LEAF STEMS



Permafrost in Action

This page from my August 2010 notebook shows decadent willows (felt-leaved willow, *Salix alaxensis*) on an abandoned stream terrace in northwest arctic Alaska. This is an un-named tributary of the Kivalina River draining the northwest edge of the Brooks Range. Although this is terrain characterized by continuous permafrost, the bare mineral surface and shallow pools of such braided tundra streams act as effective solar collectors. This causes permafrost to retreat to substantial depth. The warmed mineral soils provide a suitable habitat for these tall and woody willows, which, in turn, produce prime moose habitat hundreds of miles beyond their usual timber-sheltered home. When streams incise and terraces are abandoned, the abandoned gravel bars begin to develop an insulating cover of mat-forming plants such as sphagnum moss, mountain avens (*Dryas octopetala*), net-leaved willow (*Salix reticulata*), bearberry (*Arctostaphylos rubra*), and crowberry (*Empetrum nigrum*). In this illustration, the bleached skeletons of willows litter the scene with a few last gasps of life. The insulating blanket of organic debris is allowing permafrost to tighten its grip. The ground surface shows prominent cracks that result from shrinkage of the soil in extreme winter cold spells. These will eventually connect to form a polygonal network that will develop into the characteristic ice wedges of permanently frozen tundra. In this area, the polygons have raised rims and depressed centers. Geologists recognize former polygons by the depressed rims and raised centers produced by the melted out ice wedges.

—Fred Paillet, 2011 (see more about Fred and his work on the inside back cover)

Mountain Views

The Newsletter of the Consortium for Integrated Climate Research in Western Mountains CIRMOUNT

www.fs.fed.us/psw/cirmount/

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Cover Photos: Jeff Hicke, Assistant Professor, University of Idaho, Moscow, ID (Front: Lamar Valley, Yellowstone National Park, WY, Back: Winter Sunrise, Colorado Rockies)

The Mountain Views Newsletter (*MVN*)

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Welcome to *Mountain Views*, the biannual newsletter of the Consortium for Integrated Climate Research in Western Mountains (CIRMOUNT, www.fs.fed.us/psw/cirmount/). With this issue, we begin our fourth year producing *MVN* and reporting news about climate research and climate adaptation relevant to mountains of western North America. CIRMOUNT is an informal consortium comprising scientists, managers, policy makers, and others interested in climate science and ecosystem responses in our region. CIRMOUNT provides a forum to integrate and communicate research from diverse disciplines, and seeks to promote awareness of, and solutions to, societal issues arising from anthropogenic impacts on the climate and biophysical systems in mountain regions of the West.

As a grass-roots consortium, CIRMOUNT has been informally advanced by coordinators who promote our community's goals whenever possible given our unfunded status. In 2004, we considered CIRMOUNT to have launched following our first major conference, which took place at Lake Tahoe, California. Biennial meetings, now known as the MtnClim Conferences (archives at: www.fs.fed.us/psw/cirmount/meetings/), have become CIRMOUNT's flagship event. *MtnClim 2010* convened in June 2010 at the H.J. Andrews Experimental Forest in Oregon. Presentations from this event are on CIRMOUNT's archive webpages.

The MtnClim Conferences alternate with our sister event, the Pacific Climate Workshops, which convenes this year in Pacific Grove, CA, March 6-9, 2011 (contact Scott Starratt, ssarratt@usgs.gov). Looking farther forward, we are planning for *MtnClim 2012*, which we hope to convene in Estes Park, CO, most likely in September 2012.

CIRMOUNT also sponsors mountain-climate sessions at the annual Fall Meeting of the American Geophysical Union (AGU)

in San Francisco. At the December 2010 AGU meeting, we convened a session entitled, *Ecosystem Responses to Fine-Scale Climate Variability in Mountainous Terrain*, our seventh year contributing to AGU. Poster and oral presentations are on the CIRMOUNT meeting archive page. Anyone interested to work with the coordinators for planning the AGU 2011 session, please contact Connie, cmillar@fs.fed.us.

In this issue of *MVN*, we welcome Jeremy Littell as co-Editor joining Connie, and once again thank Henry Diaz for his dedicated work to found and edit the first three years of *MVN*. We are making a few changes to format with this issue. For one, we have added a *BREVIA* section, which includes short summaries of just-published or soon-to-be published research articles of interest to our community. In this Winter 2011 issue, we focus *BREVIA* articles on early-career scientist authors.

With this issue, we have also added emphasis to the artistic sides of our community. While our primary voice remains the technical medium, photography, drawings, and poetry are powerful illuminators of process, as well as important reflections of why many of us came into the field: our love for mountain environments. We hope you appreciate the contributions of our scientist-artists, including Jeff Hicke (photography), Bob Coats (poetry), and Fred Paillet (sketching). Please let us know if you would like to contribute to these sections.

From around the West, snowing or sunny, we send our best wishes for a productive and joyful mid-winter season.

On behalf of the CIRMOUNT coordinators,

— Connie and Jeremy

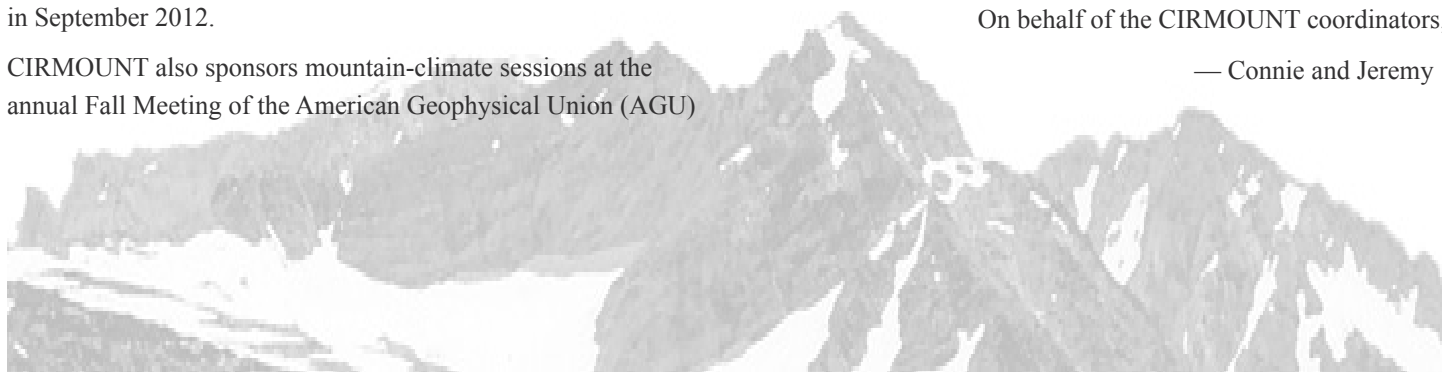




Figure 2. Old-growth stands of bristlecone pine (*Pinus longaeva*) growing on the east slope of Mt. Washington, Snake Range, NV near the uppermost site in the southern EPSCoR transect (photo, C. Millar).

Partnerships and Collaboration

A number of close partnerships have sprung from the project, and in fact collaboration with multiple stakeholders is essential for project sustainability. In the Snake Range, sites are located on land owned by the Long Now Foundation (www.longnow.org/), the Nevada Land Conservancy (www.nvlc.org/), and the Bureau of Land Management (www.blm.gov/nv/st/en/fo/ely_field_office.html). In the Sheep Range, all sites are found within the Desert National Wildlife Refuge managed by the Fish and Wildlife Service (www.fws.gov/desertcomplex/desertrange/). An exciting feature of the transects is that all sensors are networked together, so that both data and images (collected from web cameras) can be streamed live to researchers' offices and to the public. The same private TCP/IP network provides high-speed internet connectivity to the remote field sites, establishing a valuable communications resource for additional equipment, project personnel, and collaborators. The backbone of this digital network relies on the infrastructure managed by the Nevada Seismological Laboratory (www.seismo.unr.edu/), which guarantees a high level of reliability even in the most remote areas. In close collaboration with the Cyberinfrastructure component of the Nevada NSF-EPSCoR project, data acquired from the transect monitoring stations will be made available through a data portal, which is currently in the final stages of preparation.

Looking to the Future

While a few focused research projects have been initiated using seed grants provided by the NSF-EPSCoR project itself, the purpose of the EPSCoR program is to build infrastructure that can be leveraged to acquire additional funding. Therefore, all project researchers are interested in building collaborations both inside and outside Nevada with other scientists interested in pursuing ecohydrological research questions. The CIRMOUNT community may be particularly interested in the high elevation sites, since the transects will include stands of five-needle high-elevation pine species, such as bristlecone pine (*Pinus longaeva* D.K. Bailey; Fig. 2), which have provided some of the longest annually resolved and continuous records of air temperature used to place instrumental records in a broader perspective. More recently, it has been reported that bristlecone trees growing within about 150 m of the upper treeline limit have reached unprecedented growth peaks in the last few decades (Salzer et al. 2009). Some of the bristlecone pines used by Salzer et al. (2009) are found within the Nevada EPSCoR transects in the Snake Range, hence it will be possible to fully test the hypothesis that bristlecone growth is a record of mean air temperature by first using detailed field data on atmospheric conditions, soil moisture, sap flow, and stem

size to determine what controls the length of the growing season. Radial changes will be measured using point dendrometers to the nearest μm at half-hour intervals (Biondi and Hartsough 2010), and repeated microcore sampling can be combined with histological analysis to determine the timing of cambium activity, subdivision, elongation, and lignification of new xylem cells during the season (Rossi *et al.* 2007). Although this is only one of many research projects being underway at the transect sites, it clearly shows how the combination of long-term monitoring sites with targeted field investigations can become a most powerful tool to achieve transformative scientific results in environmental science.

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BREVIA

The Story Behind the Paper: “Relationships Between 4 Barrier Jet Heights, Orographic Precipitation Gradients, and Streamflow in the Northern Sierra Nevada”

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Lundquist, J. D., J. Minder, P. J. Neiman, and E. Sukovich. 2010. *Relationships between Barrier Jet Heights, Orographic Precipitation Gradients, and Streamflow in the Northern Sierra Nevada*, *J. Hydrometeorology*, 11: 1141–1156

In the Beginning...

My original goal was to model streamflow in the Tuolumne River in Yosemite National Park, California (Fig. 1). The model (DHSVM, Wigmosta et al. 1984) matched observed streamflow fairly well up until 2007, when it was off by a factor of two (Fig. 1)! What could have gone wrong in 2007? For an error of that magnitude, the only explanation was that we put too much water (precipitation) into the model, but only in that year.

Testing

We investigated our fundamental premise. We used meteorological data at Dana Meadows, where, because all precipitation falls in the form of snow, we used the snow pillow, which determines the accumulation of water equivalent by weighing the snow, to determine how much precipitation fell each day. We then used the Parameter Regressions against Independent Slopes Model (PRISM, Daly 1994) to distribute precipitation across the basin. This method assumes that the ratio between the mean precipitation at the measurement point and the precipitation at each 800 m grid cell in the watershed is constant throughout time. Incremental measured precipitation is then multiplied by that ratio to input precipitation at each time-step at each grid cell in the model. Hypothesis 1: Perhaps, the distribution of precipitation in 2007 was different than the average. Perhaps the ratio between Dana Meadows and the rest of the watershed was less in 2007 than on average. We searched for supporting evidence. 1) In most years, the storms bringing precipitation to the Sierra Nevada come from the southwest. However, in 2007, the storms had a more directly westerly or northwesterly approach. Thus, winds would approach

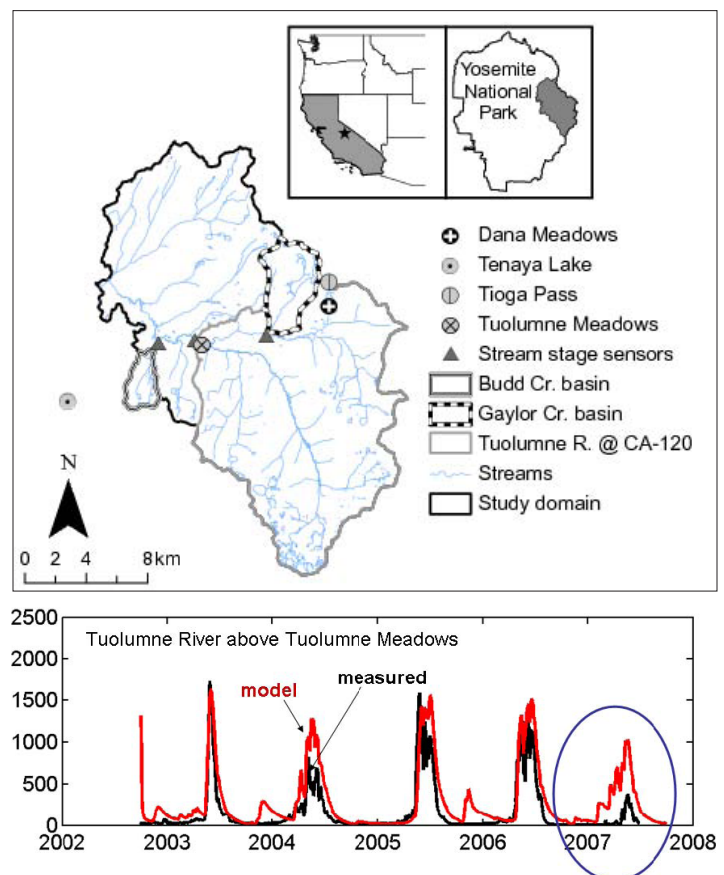


Figure 1. Tuolumne River basin map and preliminary model results (based on model simulations run by Fred Lott and Jeffrey Deems). Note that modeled streamflow is twice as great as observed streamflow in 2007.

the mountains at a different angle, resulting in different areas of orographic enhancement to precipitation and likely different precipitation patterns. 2) In most years, Slide Canyon, a snow pillow slightly to the northwest of the watershed, received 1.5 to 2 times the annual snow accumulation as Dana Meadows. In 2007, the two sites reported identical amounts of snow. Yes, it appeared that 2007 had a different precipitation distribution than the average, likely due to different storm trajectories. Could we predict the changing precipitation distribution and thus improve

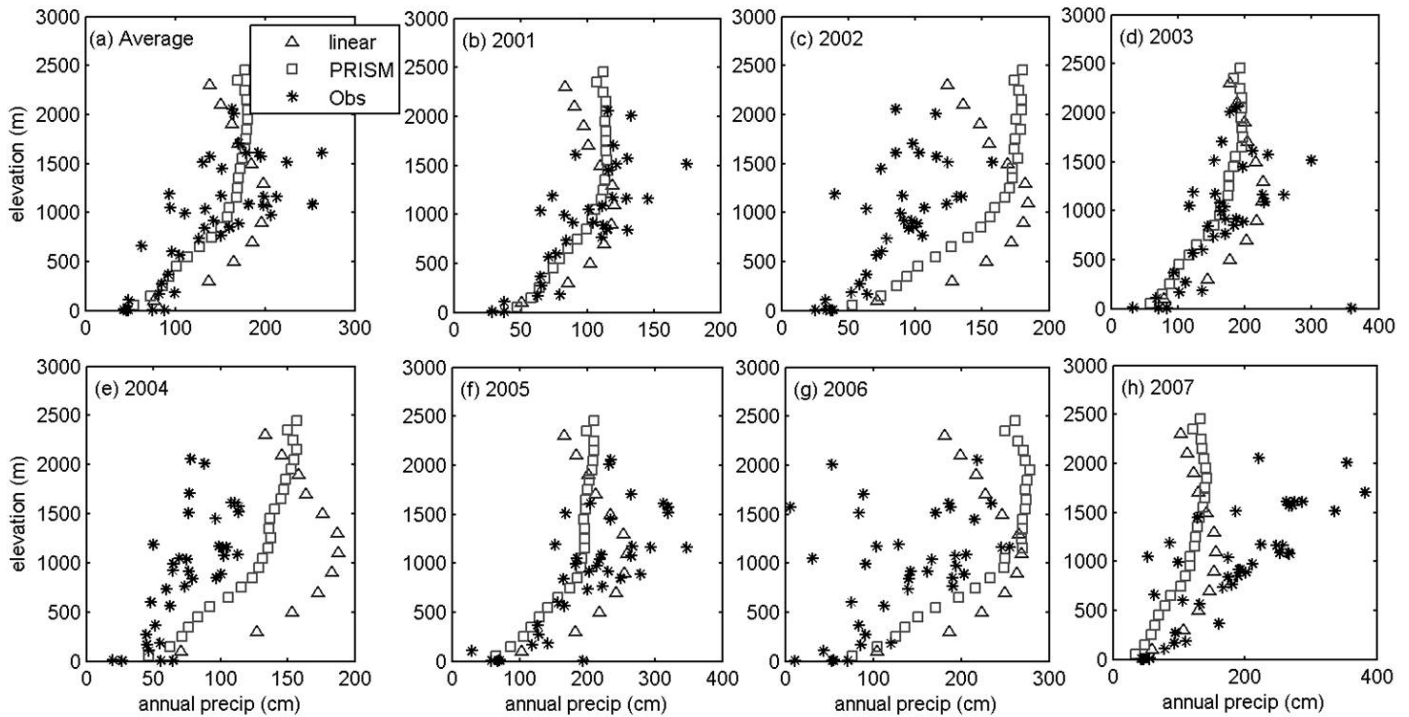


Figure 2 (reprinted from Figure 5 in Lundquist et al. 2010). Annual precipitation accumulation as reported by precipitation gages in the Northern Sierra (Obs), a linear model of orographic precipitation forced with Oakland sounding information, and 4-km resolution PRISM maps of interpolated surface precipitation measurements for (a) the median of all elevations for the mean of water years from 2001 to 2007, and (b) through (h) the median of each elevation for each water year. Note the difference between PRISM, the linear model, and observations at higher elevations in 2007.

our snow and streamflow modeling, so that we could properly model streamflow in 2007? We postulated that a linear model of orographic precipitation (which takes into account wind direction and static stability) would be able to improve our predictions in years with a different wind direction. We also postulated that monthly 4-km PRISM precipitation data (which varies from one year to the next) would provide improvement over the climatological normals we had been using.

An Explanation

However, there were too few precipitation gages in the central and southern Sierra, and so we moved to the Northern Sierra (the Feather, Yuba, and American River basins just east of San Francisco), where we had 124 daily-resolution (four of which also had quality-controlled, hourly resolution) precipitation gage records, spanning elevations from 0 to 2100 m, to test our hypotheses. The results are detailed in Lundquist et al. (2010) and summarized here. Both a linear model of orographic precipitation forced by upstream radiosonde data and monthly PRISM precipitation data were able to represent average precipitation distributions well in the mean. However, in some years (2007 included), both

methods failed (Fig. 2). The reason for these failures was associated with the Sierra barrier jet (SBJ), which occurs when an air-mass approaching the Sierra Nevada is partially blocked by the mountains, resulting in some air turning to the left and traveling parallel to the mountain range instead of across it. During years when less than 30% of the precipitation occurred on days with SBJs, the linear model and PRISM could represent annual patterns of precipitation. However, neither the linear model nor PRISM adequately captured orographic precipitation patterns during years when more than 70% of the precipitation occurred on days with SBJs.

Additionally, the mere presence or absence of a barrier jet was not enough to inform about precipitation patterns. Throughout all years, wind profiler data indicating the height of the SBJ (that is, the vertical extent of the wind moving parallel to the mountain range) provided additional, and necessary, information. The increase in precipitation with elevation is negatively correlated with the height of the SBJ, such that there is little, if any, increase in precipitation with elevation during very deep SBJs. The SBJ height is lower, and hence, the increase in orographic precipitation with elevation greater, when the westerly winds are stronger,

with more vertical wind shear. These westerly storms result in greater increases of precipitation with elevation, which act to increase snow storage in most storms but also to increase storm runoff during warmer-than-average storms.

Thus, a greater-than-normal fraction of shallow SBJs in 2007 could explain the differences between precipitation observations and PRISM predictions in 2007 in the Northern Sierra Nevada (Fig. 2). But, could this knowledge help us back in Yosemite? Sadly, no. The southern Sierra Nevada are much higher than the northern Sierra Nevada, resulting in more airflow being blocked, and a linear model of orographic precipitation cannot represent mean precipitation patterns correctly, let alone potential variations. 2007 was likely different from the norm, but there's no reason to assume that the way it differed in the southern Sierra will match the way it differed in the northern Sierra. There are also much fewer measurements available to test hypotheses.

However, in summer 2009, we came up with a more brilliant solution: visit the measurement site at Dana Meadows (Fig. 3). Snow pillows work like truck weights, with four metal "pillows" filled with antifreeze hydraulically connected via pipes to a reservoir with a plumb bob with rises as increasing pressure is placed on the pillows. We found a small lodgepole pine growing in the middle of the Dana Meadows snow pillow. With the permission of Frank Gehrke, the head of the California Snow Surveys, we removed the tree (Fig. 3). Real-time data (unedited) on the California Data Exchange Center (CDEC) website reported 4 inches of SWE before the tree was removed and -8 inches of SWE after it was removed (a difference of 12 inches!). Apparently the trees roots had been putting pressure on the snow pillow for some time, which was interpreted as additional snow pack. During the summer, this was edited out, but during the winter, it appeared that much more snow had fallen on the pillow than really did. We set up our hydrologic model to run with precipitation measurements from a different location and were able to simulate streamflow reasonably well in all years (including 2007).

So, the moral of this story is that precipitation distributions do change and are important, but the errors due to changing patterns of precipitation are much smaller than those that can arise from compromised measurements! Watch out for trees in snow pillows.



Figure 3. Tree growing in the center of the Dana snow pillow (top), and removal of tree on 25 June 2009 by (from left to right) Alan Flint, Courtney Moore, and Lorrie Flint. Real-time data (unedited) on the California Data Exchange Center (CDEC) website reported 4 inches of SWE before the tree was removed and -8 inches of SWE after it was removed (a difference of 12 inches!) (photo, J. Lundquist).

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BREVIA

Climatic Controls on the Snowmelt Hydrology of the Northern Rocky Mountains, USA

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Pederson, G. T., S. T. Gray, T. Ault, W. Marsh, D. B. Fagre, A. G. Bunn, C. A. Woodhouse, and L. J. Graumlich: Climatic controls on the snowmelt hydrology of the Northern Rocky Mountains, USA. Journal of Climate, Early on-line edition, 22, doi: 10.1175/2010JCLI3729.1

Critical Mountain Snowpack Reservoirs

Much of the western U.S. and Canada is characterized by an arid to semi-arid climate, and the majority (50 to 80% or more) of surface water in this region originates from mountain snowpack (Bales et al. 2006). A growing number of studies have demonstrated that since 1950, western North America has experienced a substantial decline in peak snow water equivalent (SWE; e.g. Mote et al. 2005; Pierce et al. 2008), a reduced and earlier snowmelt runoff (e.g. Hidalgo et al. 2009; Stewart et al. 2005), with a substantial proportion of the observed declines linked to anthropogenically driven increases in winter and spring minimum temperatures (e.g. Barnett et al. 2008). Documented changes in both the quantity and temporal characteristics of snowpack and streamflow across the western U.S. have important implications for water resources and biophysical processes in high-mountain environments. In a forthcoming study (Pederson et al. *in press*), we build upon previous work by investigating the oceanic and atmospheric controls underlying changes in timing, variability, and trends documented across the entire hydroclimatic monitoring system within critical Northern Rocky Mountains (NRM) watersheds. This study was motivated, in part, by increasing pressure on state and federal resource management agencies to incorporate this type of climate information into sustainability- and adaptation-planning efforts. Additionally, the region serves as a critical headwaters area, is arguably one of the most intact and functional temperate ecosystems in the world, and contains a number of the longest-running, high-resolution stream gage, meteorological, and snow observation stations in North America.



Figure 1. Measuring winter snowpack in the Northern Rockies (photo, G. Pederson).

Decreased Snowpack and Earlier Melting

Analyses were conducted using records from 25 snow telemetry (SNOTEL) stations, 148 April 1 snow course records, stream gage records from 14 relatively unimpaired rivers, and 37 valley meteorological stations. Daily SNOTEL SWE data were used in analyses of snowpack dynamics, and results are most representative of changes occurring at mid-elevations (avg. station elevation = $1743 \text{ m} \pm \sigma 259 \text{ m}$) (Fig. 1).

Over the past four decades, SNOTEL records show a tendency towards decreased snowpack with peak snow water equivalent (SWE) arriving and melting out ~ 8 days earlier, with an average of 14 more snow-free days per year. Corresponding with the changes in snowpack, temperature records show significant

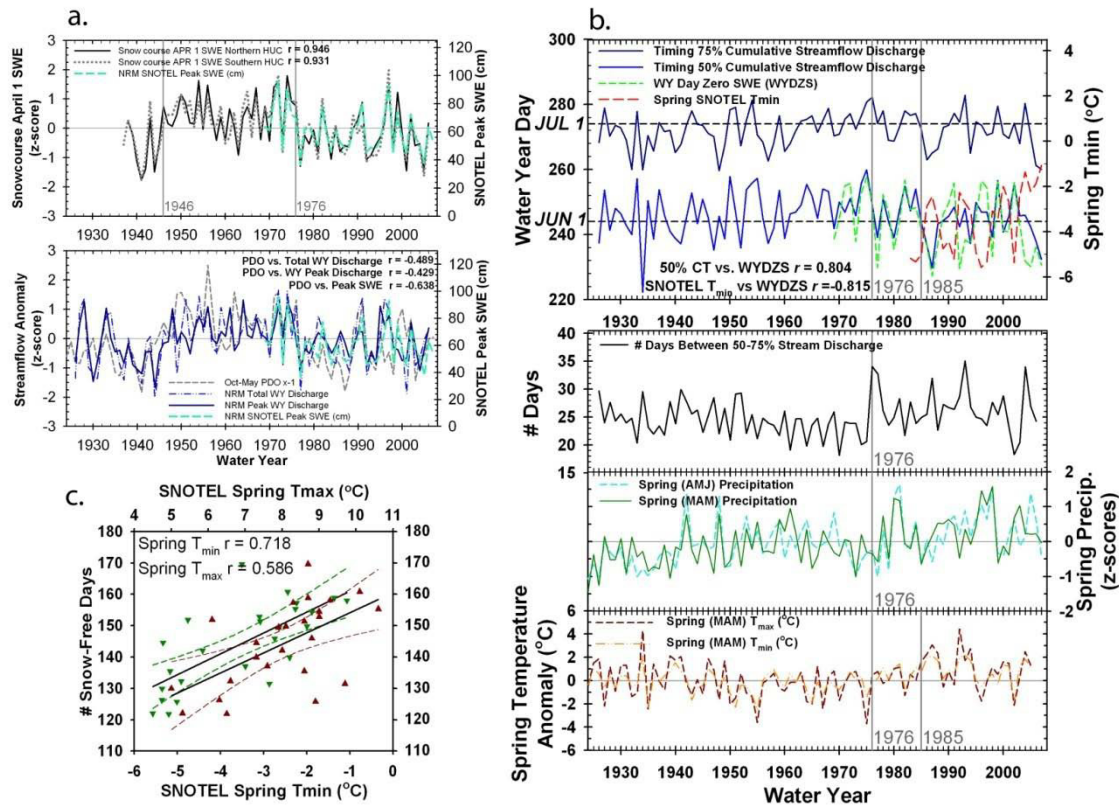


Figure 2. Amount and melt-out of snowpack and streamflow. A. Co-variability between snowpack, streamflow, and North Pacific SSTs. B. and C. Relationship between the timing of streamflow, melt-out of snowpack, number of days without snowcover, and spring temperature and precipitation.

seasonal and annual decreases in number of frost days (days $\leq 0^{\circ}\text{C}$), and changes in spring minimum temperatures that correspond with atmospheric circulation changes and surface-albedo feedbacks in March and April. The amount and melt-out timing of snowpack and streamflow in the NRM is strongly controlled by warming spring temperatures, increasing spring precipitation, and changes in winter stormtracks associated with variations in Pacific Ocean sea-surface-temperatures (SSTs; Fig. 2). Records of snow course April 1 SWE show the composite time-series are good metrics of SNOTEL peak SWE, and that since 1936 a major feature of the records is the strong variability on interannual- to decadal-scales that coincide with changes in streamflow discharge, and North Pacific SSTs. Spring temperatures coupled with increases in the mean and variance of spring precipitation control the timing of snow melt-out, an increased number of snow-free days, and observed changes in streamflow timing and discharge. Importantly, increased spring precipitation after 1977 appears to substantially buffer streamflow timing from what should otherwise be a considerably earlier decline in flow due to the recent decades of low snowpack with above-average temperatures.

The atmospheric controls shown to underlie observed changes in temperature, snow melt-out, and runoff, also control multiple phenological and ecological aspects of spring onset across west-



Figure 3. Diminishing snowpack and earlier run-off assessed in the Northern Rockies have implications westwide that major changes are in store for aquatic and terrestrial ecosystems (photo, G. Pederson).

ern North America. This implies that the associated snowmelt related ecosystem impacts are much broader than the Northern Rockies study area, and if regional projections of 21st century hydroclimatic change prove correct, major changes are in store for aquatic and terrestrial ecosystems, and consequently land and water resource managers (Fig. 3).

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BREVIA

Quantifying Recent Ecological Changes in Alpine and Arctic lakes of North America

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Hobbs, W.O., R.J. Telford, H.J.B. Birks, J.E. Saros, R.R.O. Hazewinkel, B.P. Perren, É. Saulnier-Talbot, A.P. Wolfe. 2010. Quantifying recent ecological changes in remote lakes of North America and Greenland using sediment diatom assemblages. *PLoS One*, 5(4): e10026, www.plosone.org/article/doi/10.1371/journal.pone.00

There is mounting evidence that recent ecological and biogeochemical changes have occurred in remote lakes, defined here as those lacking any immediate, catchment-scale, anthropogenic influences (Fig. 1). The implication is that these ecosystems can no longer be considered pristine, largely because of their high sensitivity to climate change (Smol et al., 2005) which, in some regions, is compounded by significant inputs of reactive anthropogenic nitrogen [hereafter Nr; comprising all biologically-, photochemically- and radiatively- active nitrogenous compounds in the atmosphere and biosphere (Galloway et al., 2004)] delivered by atmospheric deposition. Part of the sensitivity of remote alpine and arctic lakes is attributable to limnological characteristics such as dilute water chemistry, low primary production, and high flushing rates associated with nival hydrological regimes.

The paucity of long-term climatic and environmental monitoring data in remote regions can be alleviated by the use of proxy data from high-resolution sedimentary records. Geochemical signatures and biological remains are continuously archived in the sediments accumulating at the bottoms of lakes. Diatoms (Bacillariophyceae) are unicellular aquatic photoautotrophs that respond rapidly to changes in water chemistry caused by environmental change (Fig. 2). Their siliceous cell walls are often preserved in lake sediments with sufficient fidelity to allow taxonomic identifications and ecological inferences based on species assemblages, thus producing an archive of limnological history. In an evolving literature, sediment diatom records augment the evidence that the planet has entered the Anthropocene (Crutzen, 2002), the era of human dominance over key biogeochemical cycles, with direct climatic and ecological repercussions.



Figure 1. Curator Lake, Jasper National Park, Alberta, Canada. Elevation 2232 m asl (photo, W. Hobbs).

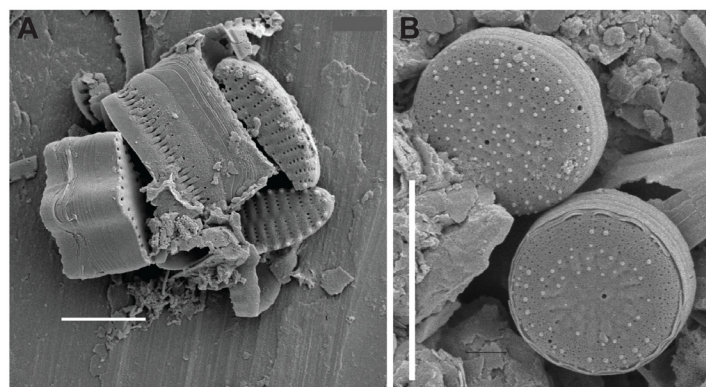


Figure 2. Scanning electron microscope images of common diatoms from benthic (A) and planktonic (B) habitats. A. *Staurosira* spp. and *Staurosirella* spp. and B. *Cyclotella comensis*, with 5 μ m scale bars. In many of the study lakes it is the relative success of planktonic diatoms over benthic taxa in the 20th century that drives β -diversity.

We synthesized 52 dated sediment diatom records from lakes in western North America and west Greenland, spanning broad latitudinal and altitudinal gradients, and representing alpine (n=15),

arctic ($n=20$), and forested boreal-montane ($n=17$) ecosystems. The turnover of diatom species assemblages (β -diversity) during the 20th century was estimated using Detrended Canonical Correspondence Analysis (DCCA) for each site and compared, for cores with sufficiently robust chronologies, to both the 19th century and the prior ~250 years (Little Ice Age). For both arctic and alpine lakes, β -diversity during the 20th century is significantly greater than the previous 350 years (Figure 3), and increases with both latitude and altitude. Because no correlation is apparent between 20th-century diatom β -diversity and any single physical or limnological parameter (including lake and catchment area, maximum depth, pH, conductivity, $[\text{NO}_3^-]$, modeled Nr deposition, ambient summer and winter air temperatures, and modeled temperature trends 1948-2008), we used Principal Components Analysis (PCA) to summarize the amplitude of recent changes in relationship to lake pH, lake:catchment area ratio, modeled Nr deposition, and recent temperature trends (Fig. 3).

The ecological responses of remote lakes to post-industrial environmental changes are complex. However, two regions reveal concentrations of sites with elevated 20th-century diatom β -diversity: the Arctic where temperatures are increasing most rapidly, and mid-latitude alpine lakes impacted by high Nr deposition rates. We predict that remote lakes will continue to shift towards new ecological states in the Anthropocene, particularly in regions where these two forcings begin to intersect geographically.

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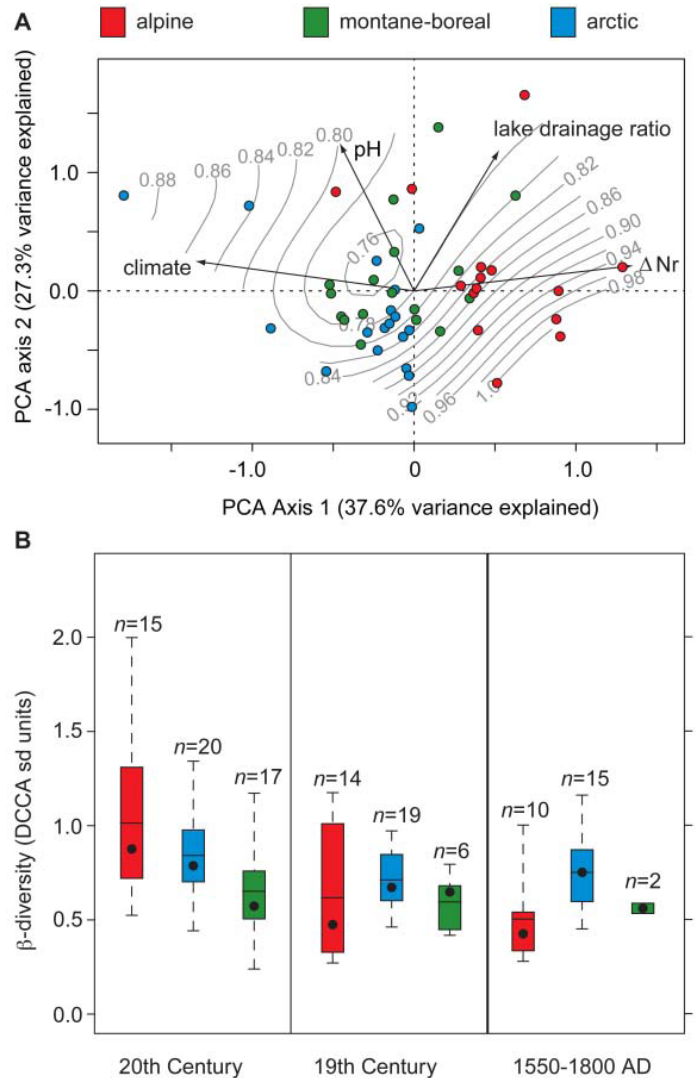


Figure 3. Trends in diatom diversity. A. PCA biplot of site-specific temperature and Nr deposition trends, lake pH, and lake-to-catchment area ratio. Twentieth century diatom β -diversity included in the PCA as a passive variable, contoured at 0.05 SD intervals using thinplate splines over the ordination space. B. Boxplots of diatom β -diversity from each lake region. Black dots represent the median value, boxes are the 25th percentile surrounding the mean value, and dashed ticks indicate range. Twentieth century results; statistically significant differences exist between alpine and montane-boreal ($p=0.003$) and arctic and montane-boreal ($p=0.004$) lakes. Results for the 19th century and 1550-1800 reveal no statistically significant differences, in contrast to the 20th century.

BREVIA

Forest Responses to Warming on the Sky Islands of the Southwestern United States

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Williams A.P., C.D. Allen, C.I. Millar, T.W. Swetnam, J. Michaelsen, C.J. Still, and S.W. Leavitt. 2010. Forest responses to increasing aridity and warmth in the southwestern United States. Proc. Nat. Acad. Sci. USA, 107:21298-21294

The mountains of the southwestern United States, here defined as Arizona, New Mexico, southern Utah, and southern Colorado, are like green islands poking out of a brown and barren sea. While the desert has many splendors that are interesting and beautiful because of their unique tolerance for heat and drought, the cooler and wetter mountains are where many of us find ourselves wanting to be during summer road trips through the Southwest. On a 2005 field trip to Mount Graham in the Pinaleno Mountains of southeastern Arizona, it was well over 100 degrees on the desert floor, but 50 degrees cooler and hailing on the mountain top. These cool and wet conditions cause Graham and many other southwestern mountains to be safe havens for pine, fir, and spruce forests. Traveling up one of these mountains and seeing the transition from hot, dry desert to cool, wet forest causes many of us to wonder how these southwestern forests responded to warming during the last century and how they will respond to continued warming in the future.

To begin answering this question, we (Williams et al. 2010a; 2010b) used records of tree-ring widths (Fig. 1) from 1,100 forest sites within the continental United States.



Figure 1. Increment cores removed from limber pine (*Pinus flexilis*) on Mt. Crested Butte, Colorado, show high interannual variability in annual ring widths that can be correlated with climatic variables.

Nearly all of the tree-ring data came from the International Tree-Ring Databank, a massive archive of annual tree-growth measurements from thousands of sites around the world. Tree-

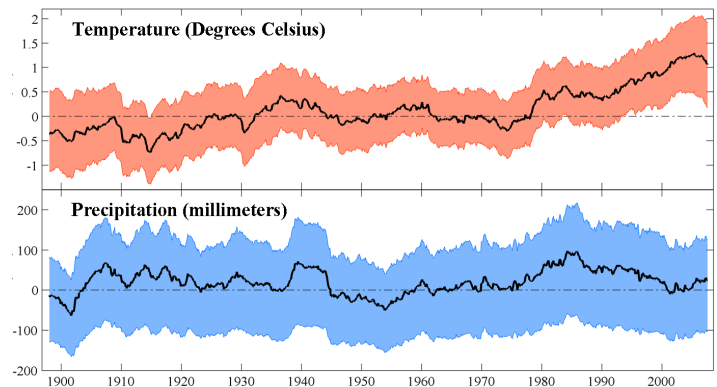


Figure 2. Southwestern forests showed high sensitivity to year-to-year variability in temperature and precipitation over the past century. Temperature has steadily increased over the past century while trends in precipitation have been much more variable. The region represented in this figure is shown in Figure 4.

ring records are great proxies for annual climate because thick rings typically grow during years of favorable climate conditions, and thin rings grow during years of poor climate conditions. By comparing each of the 1,100 tree-ring records to records of annual climate, we found, not surprisingly, that forests growing in the Southwest are far more sensitive to drought than forests elsewhere in the continental US. Importantly, southwestern forests tend to be equally sensitive to both warmth and precipitation declines, whereas many other drought sensitive forests, such as those in California, are much more sensitive to precipitation declines than temperature increases (Fig. 2).

Importantly, climate variations in the Southwest during the last century included annual to decade-long wet or dry and cool or warm periods, but the most recent decades were remarkable for a “double whammy” combination of extreme drought and exceptional warmth. The hot drought of the past two decades resulted in reduced tree growth, and also contributed to extensive tree mortality in forests and woodlands due to bark beetle outbreaks and wildfires (Fig. 3).

Computer climate models all project rapid warming in the Southwest, but they are still at odds regarding how southwestern precipitation may respond to global warming. Our finding that



Figure 3. Increasing warmth and multi-year drought are creating a 'double whammy' combination of conditions that lead to increased forest mortality throughout the Southwest (photo, P. Williams).

southwestern forests are sensitive to warmth and precipitation suggests that, barring a major increase in precipitation, warming of even a couple degrees Celsius will cause intensified water limitations and substantial growth-rate declines in southwestern forests.

Do the results of our tree-ring analyses mean there will be increased forest mortality in the Southwest? To address tree mortality we used satellite and aerial survey data to estimate the percent of southwestern forest area recently affected by tree mortality due to severe wild fires and bark beetles. In the map (Fig. 4), red represents forest and woodland areas impacted by wildfire-induced mortality since 1984 and orange represents areas impacted by bark beetle-induced mortality since 1997.

The forest areas were most severely affected by the combination of bark beetles and wildfire, with about 18% of forest area affected (i.e., about 18,000 square kilometers). Unfortunately, historical data do not exist to tell us just how abnormal these high levels of mortality are. We also do not know how much of this mortality is attributable to warming and increased drought; both increasing fuel loads created by fire suppression and increasing human-caused ignitions due to population growth have surely had an impact. While there is much we still don't know, we do know that

drought stress makes trees more susceptible to severe wildfires and bark beetle outbreaks. Several hundred years of tree-ring records from the western United States indicate that drought years have been historically associated with increased regional fire activity (Swetnam and Betancourt 1998), and warming trends in the late 20th century are associated with the recent increase in large forest fires across the western U.S. (Westerling et al. 2006). Bark-beetle research shows that increased warmth and drought are partly related to big increases in beetle populations (Raffa et al. 2008). Our study builds upon this previous research. Since the mid-1980s, warming and decreasing precipitation in the Southwest coincided with increasing forest mortality due to both bark beetles and severe wildfire. Furthermore, the most severe drought years of the century, 2002 and 2003, were far and away the years with the most southwestern forest area killed by bark beetles and severe wildfire.

While rainfall will continue cycling through dry and wet periods, temperature is very likely to continue rising. We can expect continued warming to suppress southwestern growth rates during both wet and dry phases. Warming will also make forests increasingly vulnerable to severe wildfires and bark beetle outbreaks during future dry phases. We may also expect that warming will gradually inhibit the abilities of forests to recover from mortality events during the wet periods.

The final message of our article is one about management. We assert that warming will bring inevitable change to many drought sensitive southwestern forest areas. In general, we find that trees growing at warm, lower elevation sites tend to be more sensitive

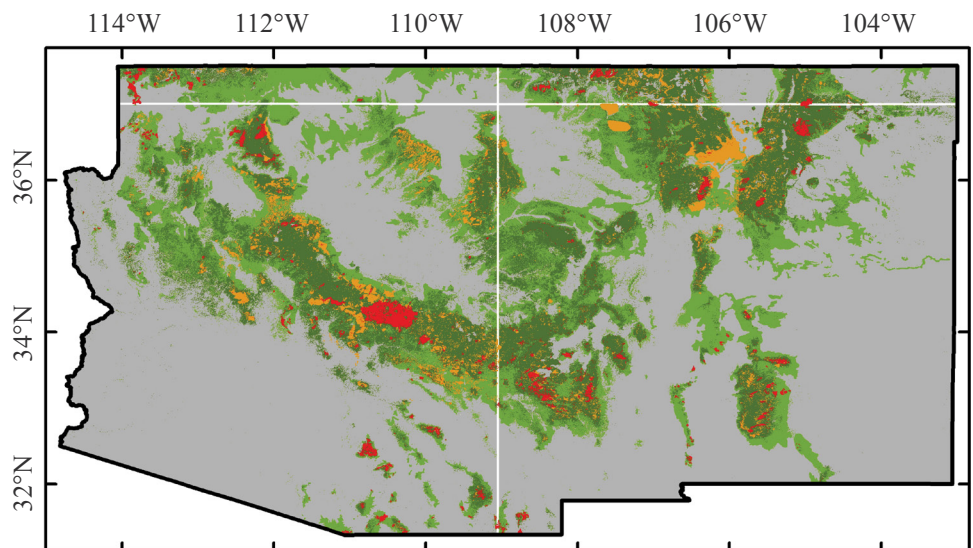


Figure 4. Wildfire- and insect-caused forest mortality in the Southwest. Dark green: dense conifer forest, light green: piñon-juniper woodland, red: area severely burned by wildfire from 1984-2006, orange: area impacted by bark-beetle induced mortality from 1997-2008.

to increased drought. In terms of active intervention, ponderosa pine and mixed conifer stands that have grown dense with many small diameter trees in the past century might be prioritized to receive the highest attention (e.g., mechanical thinning and prescribed fire) because these areas are likely to experience more high severity fires and beetle outbreaks in coming decades.

Keep in mind that our study only identifies general tendencies for the region. Local experts are crucial in identifying the most vulnerable targets for management, and the tradeoffs in risks and costs. When the money is available, managing to resist undesired change to the most valuable resources is a defensible short-term goal. Although this might seem to deny the inevitability of change, there are local situations where such labors and expenses are appropriate short-term measures to stop rapid change in places with highly valued species and ecosystems (e.g., rare plant species habitats and ancient groves). At larger spatial scales, it may be more appropriate to use treatments where the goal is to promote sustainability by increasing resilience to drought, bark beetles, and wildfire. Resilience goals may aim to maintain forest communities rather than allow conversion to scrubland or grassland, despite the likelihood of significant changes in stand density and species composition within forests. For example, fuel-reduction treatments are commonly prescribed to promote health of stands and increase ecosystem resilience. Recognizing and promoting genetic adaptation by enabling natural selection processes of selective survival and mortality is another resilience strategy.

Assisting the transition to new ecosystem states and developing adaptation strategies for the longer term involves acknowledgment that many southwestern forests in locations sensitive to fire and insects/disease may convert to non-forest vegetation types. Managing for adaptation means trying to sustain desired long-term ecosystem functions and services such as air-quality protection, soil and watershed health; promotion of native plants and animals; and maintenance of diverse amenity functions, even in the face of eventual loss of forest cover in many areas.

Restoration efforts in changing forest ecosystems must move beyond frameworks where the goal is to recover historic forest structure and composition. A more general and effective goal is to maintain and restore ecological processes achieved by means of creative manipulation. For instance, we may consider using new mixtures of native plant species (and genotypes) and planting native species into novel locations. A fundamental requirement of all approaches to sustainability in the face of high uncertainty is the capacity to conduct and carry out long-term monitoring and adaptive management strategies. We must learn from the ecological changes that we observe and manage for adaptation at local through national policy levels in order to sustain southwestern forests and ecosystem services in the face of inevitable climate challenges.

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Ecosystem Restoration in the Time of Climate Change; The Mono Lake Basin, California

An Interview with Greg Reis, Information Specialist, Mono Lake Committee

Recently I was asked by a US Forest Service team to provide examples where ecological restoration projects effectively address and incorporate climate considerations. The case of the Mono Basin came immediately to my mind. On a gleaming winter afternoon in late January I spoke with Greg Reis of the Mono Lake Committee in their Lee Vining, California office. In this article I have retained English units throughout, given that many of these values have become iconic as a result of court-ordered targets and reference points. – Ed. (cim)

Mono Lake Basin Background

The Mono Basin straddles the eastern escarpment of the Sierra Nevada, defining the boundary of the Sierran province to the west and Great Basin to the east (Figs. 1, 2). At the heart of the Mono Basin lies Mono Lake, a relict of Pleistocene Lake Russell, internal draining and with salinity more than twice the Pacific Ocean. Streamwaters rush down the eastern Sierra Nevada from crests nearly 7000' above the lake, which stands now at 6382' asl. The lake ecosystem is famously productive. With high salinities and alkalinity, fish are absent, allowing benthic and planktonic algae to bloom, providing the base of the food chain. Primary consumers are aquatic arthropods, such as brine shrimp (*Artemia monica*) and brine flies (*Ephydra hians*), which are present in great abundance. These in turn support a diverse migratory as well as endemic waterfowl fauna. As much as one-third of North American eared grebes (*Podiceps nigricollis*) and one-quarter of California gulls (*Larus californicus*) depend on Mono Lake as critical habitat. Rich riparian and bottomland forests, as well as diverse littoral and lagoon environments, historically added keystone habitat in this semi-arid steppe ecosystem.

The Mono Basin lies at the top of a complex diversion system that supplies water to the Los Angeles metropolitan region, 330 miles distant. In 1941, Los Angeles Department of Water and Power (LADWP) began diverting the tributary rivers that support Mono Lake. The surface level of Mono Lake pre-diversion was 6417'. Lake levels dropped steadily over subsequent decades, reaching an historic low in December, 1981 of 6372' (Fig. 3). Salinity increased in the lake, threatening the benthic and planktonic communities and stability of the entire food chain. Tributary streams dried, lagoons disappeared, and riparian and bottomland forests died.

After more than a decade of ecosystem research, as well as a series of complex legal challenges that positioned water diver-

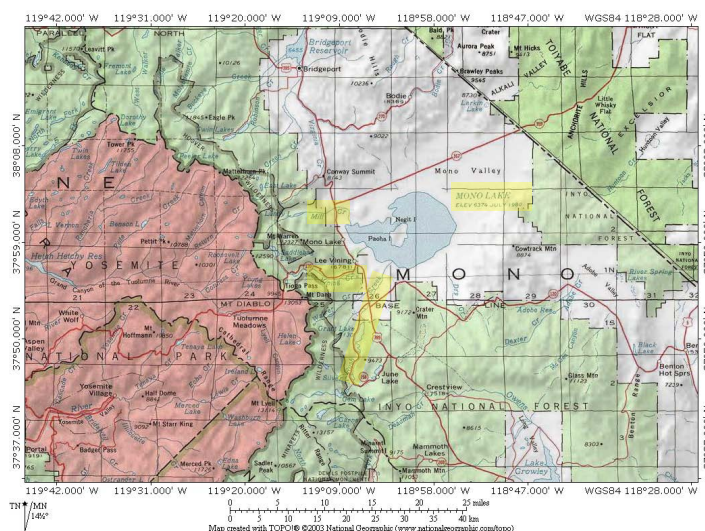


Figure 1. The Mono Basin, showing major tributaries whose waters support the lake level as well as critical littoral and riparian ecosystems of this semi-arid mountain watershed.



Figure 2. The Mono Basin straddles the boundary of the Sierra Nevada and Great Basin ecoregions, with streamflow from mountain snowpack supporting lake, riparian, and littoral ecosystems (photo, D. Simeral).

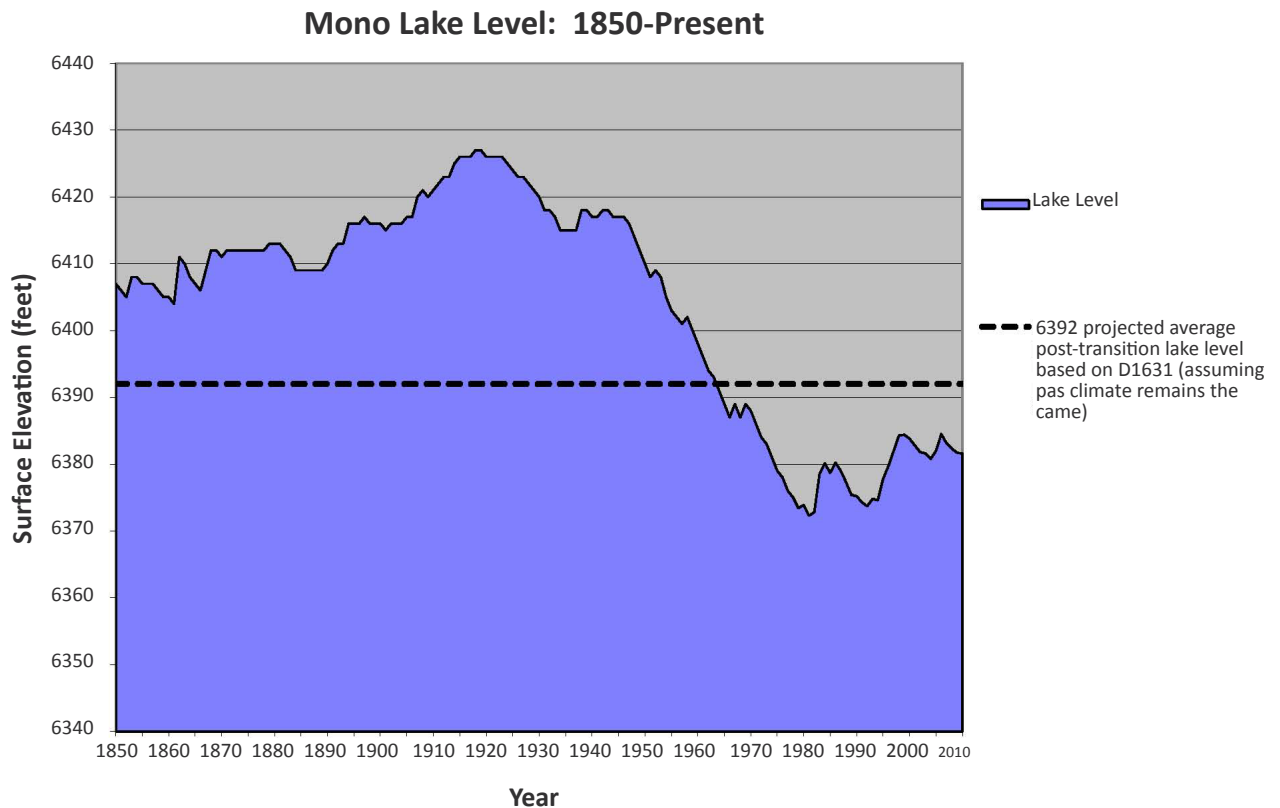


Figure 3. Surface lake levels (feet above sea level) of Mono Lake from 1850 CE to present.

sion versus ecosystem protection, a decision was reached in 1994, mediated by the California State Water Board (D1631). This decision established a target lake level of 6392' to restore the Mono Lake ecosystem, as well to re-establish streamflow levels that would restore healthy river fisheries and to ensure that public trust values (air quality, scenic and wildlife values) were protected. Requirements for water release and exports in the 1994 decision were based on a water-balance model developed for the Mono Basin. From the model, the time needed to reach the target level of 6392' was projected to range between 9 and 38 years.

In 1998, the State Water Board issued another order specifically outlining restoration goals, thresholds, and monitoring at Mono Lake. Key features of the final Mono Basin Restoration Plan include restoration of flow regimes on the streams that are based on a natural hydrograph; a stream monitoring program that would be the basis for adaptive management of stream work over time and the means of measuring when restoration and monitoring would be complete; reopening of abandoned secondary channels on tributary streams; raising the lake to 6,392' for waterfowl habitat; improving existing freshwater ponds for migrating waterfowl; and annual aerial monitoring of waterfowl and waterfowl habitat (Fig. 4).

Given the central focus on water and streamflow delivery in the State Water Board 1994 decision and the 1998 Restoration Plan, climate in turn has played a key role in influencing much of the restoration program, as well as setting restrictions and allowances for LADWP diversions.

Connie: How did the 1994 State Water Board decision take into account seasonal and interannual variability in precipitation, snowpack, and runoff?

Greg: D1631 set complex requirements for how much water LADWP could export (divert) and how much must be released into the streams and thus into the lake. The model used in developing these restrictions and allowances, and the annual scheduling of activities, took into account historic hydrologic variability by using actual historic monthly precipitation and runoff data for the years from 1941 to 1990. The monthly evaporation percentage of the annual average estimate was calculated from observed lake levels. Further, requirements and restrictions from D1631 to LADWP depend on estimated conditions for the spring runoff. On April 1st every year, projections based on snowpack and precipitation are used to place the coming year into one of seven hydrologic categories, ranging from extremely dry (e.g., 2007)



Figure 4. Freshwater ponds in the Mono Basin provide key habitat for migratory seabirds, such as California gulls, which use these waters to refresh from the high salinities of Mono Lake (photo, C. Millar).

to extremely wet (e.g., 1995). Each category in conjunction with the observed lake level describes in quantitative detail, the export rules, and releases for the coming runoff year (April through March).

Once Mono Lake reaches 6,391', D1631 models anticipated that the level would fluctuate about 12' in elevation around a median elevation of 6,392'. During wet periods, the lake could rise as high as 6,400', and during extreme drought, drop as low as 6,388'. These ranges derived from projections of interannual variability based on the conditions observed in the past.

Connie: Did the water balance models on which the D1631 plans were based take into account changing future climates?

Greg: The models did not but the decision did. D1631 states: "...future hydrologic conditions may differ significantly from historical conditions. If there were a series of extremely wet years, for example, Mono Lake could reach an elevation of 6,391' in much less than 20 years. Similarly, an extended series of very dry years could lengthen the period before 6,391 feet is reached. Un-

der the circumstances, there is limited value in attempting to fine tune computer model projections of inherently uncertain conditions many years in the future. If future conditions vary substantially from the conditions assumed in reaching this decision, the State Water Board could adjust the water diversion criteria in an appropriate manner under the exercise of its continuing authority over water rights." If, by 2014, Mono Lake hasn't reached the target level, which is likely, the State Water Board will hold a hearing to evaluate the condition of the lake to determine if new restrictions are appropriate.

Connie: What are you (Mono Lake Committee, the Stream Scientists) doing differently these days to incorporate climate-change projections and other considerations of climatic variability into your thinking about:

Streamflow Levels?

Greg: The Stream Scientists [mandated to lead the restoration and monitoring under D1631] ran warmer climate scenarios in their stream temperature model, including a conservative 2°F in-

crease in air temperatures over the next 10-25 years. On the basis of model outcomes,

they recommended keeping Grant Lake Reservoir [which is situated along the course of the most important tributary, Rush Creek] at a higher level. This higher level would be needed to ensure that Rush Creek water temperatures below the Reservoir remained cool enough to support D1631-mandated healthy trout populations. Further, based on the projections of 2°F increase in air temperatures, in years when Grant Lake Reservoir is low, the scientists recommended augmenting Rush Creek with colder [upstream] Lee Vining Creek water. They also included a climate-change chapter in their 2010 Synthesis that postulated effects of climate change on future changes in peak streamflow timing and magnitude, decreases in late-summer run-off, and reduced-width riparian corridor.

Riparian Restoration Efforts?

Greg: D1631 did not set specific riparian corridor width or biodiversity targets, but restoring riparian communities is a Mono Lake Committee goal. With drought, the lower level of Mono Lake, and diversion-related loss of the riparian forests, the tributary streams have continued to incise deep channels in the center of the once-multiple-channeled bottomlands. As a result, it may become difficult or impossible to spread the water sufficiently to restore and maintain the original broad riparian corridors we had planned for. We remain uncertain about how riparian width might respond to a restored stream channel, a revised streamflow regime, and changing climates, and for that reason, our riparian monitoring remains extremely important for adaptive management.

Monitoring?

Greg: I think we recognize that monitoring is more important than ever in light of climate change. We can at least document the changes even if we can't do anything about them. The Mono Lake Committee is motivated to ensure that long-term monitoring of key variables continues on a schedule that allows for adaptive management and an understanding of how the ecosystem is changing. Annual grebe monitoring that has traditionally occurred on Oct. 15th may need to change to match changes in timing of the grebe migration. And although LADWP has proposed to reduce limnological monitoring, the Committee is resisting

due to the uncertainties imposed by changing climates on future health of the lake's aquafauna. Gull monitoring will continue in all probability, given the importance of how climate change could affect gull populations in regard to amount of freshwater at the stream deltas, lake levels [at low levels, the island breeding habitats become connected to the mainland and to predators invasion], and productivity of the lake aquatic ecosystem.

Connie: How have you discussed the role of climate change in regard to restoration with the Mono Lake Committee membership? How do you use issues about climate change as an opportunity for interpretation and education?

Greg: The challenges of climate change are forcing us to try to be more realistic and flexible about restoration goals, and to realize that pre-diversion conditions are likely unachievable: We are in a different climate era than 75 years ago. We have raised the climate issue generally and specifically with members in newsletters, website, seminars and other venues for over a decade and regularly try to incorporate climate into our education and interpretation messages. Because Mono Lake has been such a good place to learn about the paleohistoric- and recent historic climates, it will continue to be a good place to help people understand future climate change. In 2007, one of our summer college interns developed a framework for incorporating climate into our interpretation plans.

One of the most immediate effects of climate change on the Committee's activities is our attempt to increase our operating efficiency and production of renewable energy. Proposals for solar, wind, hydro, geothermal, and other projects in and near the Mono Basin have more potential for altering the ecosystem in the short term than the actual change in climate. Changing habits and energy use will also have big effects on our infrastructure and built communities and patterns of visitation. The Committee seeks to provide science bases for recommendations on these projects via input from our Mono Science Council.

For more information, visit the Mono Lake Committee's website: www.monolake.org

Global Change and the World's Mountains: An Assessment of the Perth Conference

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An international conference, Global Change and the World's Mountains, convened in Perth, Scotland, September 26-30, 2010, under the sponsorship of the Mountain Research Initiative, Centre for Mountain Studies Perth College, and UNESCO Sustainable Mountain Development Chair. In this article, Greg Greenwood assesses the values and outcomes of this conference. - Eds.

The penultimate session of the Perth 2010 conference provided an assessment of the entire conference in terms of research gaps and emerging issues. This assessment process was developed by Astrid Björnsen of Mountain Research Initiative (MRI) and Susanne Wymann of the Centre for Development and Environment, University of Bern, using consultation and synthesis, usually after the close of sessions and before dinner, by a wide number of actors, especially session chairs, and funneling insights toward the five speakers of this next-to-last session (Fig. 1). The presentations of these five speakers are available on the MRI website (see below).

Martin Price used geography and the framework of the Global Land Project (GLP) to analyze the range of papers submitted to the Conference. He found a strong plurality of papers submitted on European mountains, with smaller numbers submitted on mountains in Asia and the Americas (Fig. 2). The numbers of papers submitted on Asian and African mountains were surprisingly high considering the low number of participants from those areas, indicating that European and North American researchers were still important in other regions.

With respect to the number of papers addressing different system elements and linkages in the GLP diagram (Fig. 3), Martin found a major emphasis on natural sciences, that is, on the state of the ecological systems in mountains, on interactions within those systems and on global environment change drivers impinging on them. Unexpectedly, the second major focus was on social systems and decision-making, especially on institutions within those systems. Interactions between the social and the ecological systems in either direction received much less attention, as did land and resource use. Global social drivers as they impacted social systems were little studied.

The next four speakers extracted strategic insight from papers presented. Eklabya Sharma (International Centre for Integrated



Figure 1. The Perth Conference on Global Change and the World's Mountains drew an attendance of over 450 participants from more than 60 countries (photo, G. Greenwood).

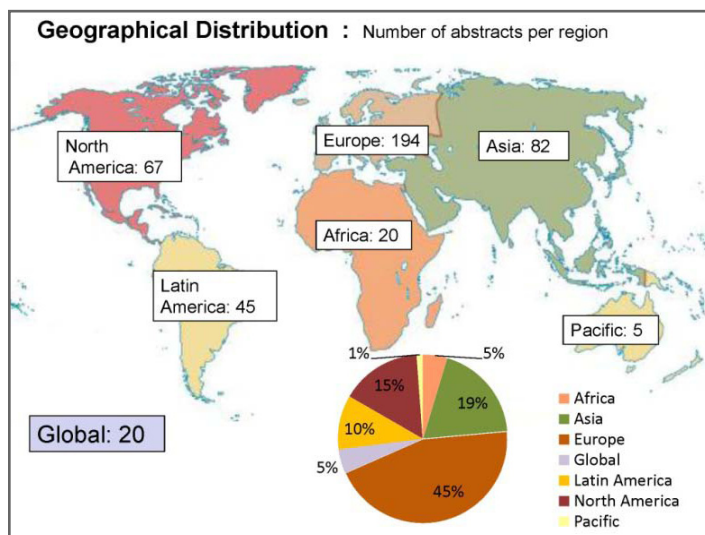


Figure 2. Abstracts submitted by region of interest

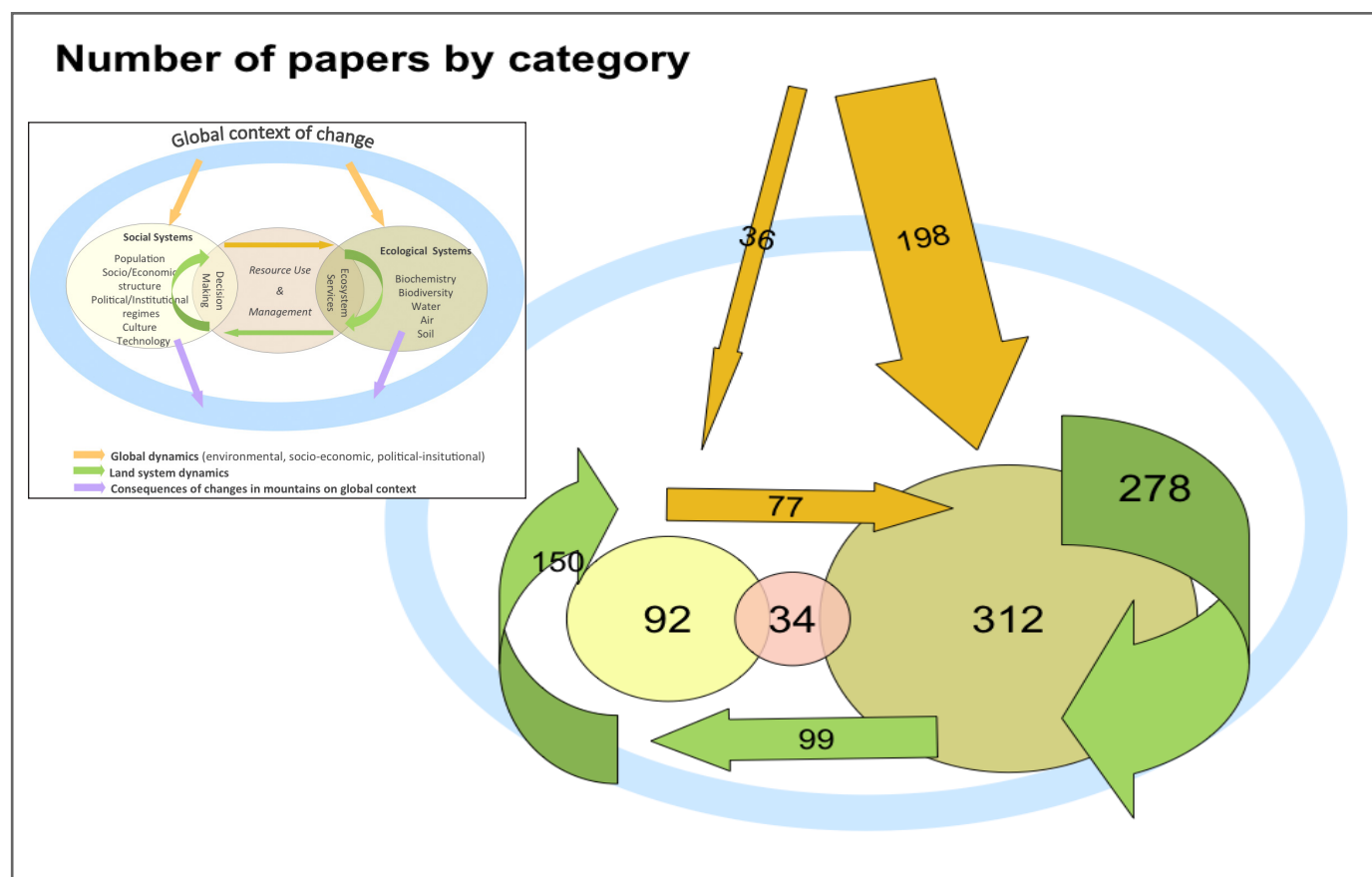


Figure. 3. Number of abstracts referring to different elements within the Global Land Project diagram (inset). Abstracts often referred to several elements; the numbers thus sum to far more than the total number of abstracts (433).

Mountain Development), Jörg Balsiger (ETH Zürich) and Jill Baron (USGS) addressed research gaps and needs, and emerging themes from the perspective, respectively, of ecological researchers, social researchers and those attempting to integrate the two. Richard Aspinall of the Macaulay Institute and the Science Committee of the GLP closed the session with reflections from the perspective of the GLP and ICSU.

Four elements were mentioned by at least two of these four speakers, and as such, can be seen as consensus strategic elements for MRI and its community.

First both Eklabya Sharma and Jill Baron mentioned long-term monitoring as a key research need. Eklabya noted a need for cost-effective and globally coordinated monitoring, while Jill emphasized the role of long-term monitoring data in creating the long-view, big-picture perspective that sustainability requires.

Second, Eklabya and Richard Aspinall emphasized ecosystem services as a research need and an organizing paradigm. Eklabya noted that while ecosystem services have been recognized,

they have thus far been poorly quantified. He saw adaptation to changes in ecosystem services in the future as an emerging issue. Richard noted that we needed yet more analytical work on ecosystem services related to their nature as either stocks consumed in places or flows from sources to sinks, and emphasized that valuation was not just financial but included aspects of health and well-being.

Third, Jörg Balsiger and Jill Baron emphasized that we have a huge research gap in understanding human agency within the system. In stressing the importance of understanding the coupled human-environment system, Jill noted that the major challenge lay in understanding how and why people make the decisions that they do. Jörg unpacked this further, emphasizing that social systems are still considered black boxes, that we do not know the drivers of individual actions, nor do we understand how these individual actions aggregate into collective behavior.

Fourth, Jill, Jörg and Richard highlighted the importance of communication, certainly with decision-makers but also with students and the public. Jörg noted our poor understanding of

how even to interest policy makers, whose interests are much broader than our research topics but whose time frame is usually quite short. He noted as an emerging theme the potential of policy-relevant research to clarify the confusion over vocabulary that currently characterizes discussions between researchers and practitioners. Jill emphasized the responsibility of researchers to educate not only their students but also their relevant publics. Richard asked, could we describe a sustainable mountain system to a policy maker in the 2 minute window that policy makers typically have? He also emphasized the issue of vocabulary, in which uncertainty and risk have quite different meanings for researchers and policy makers.

Each of these speakers offered particular insights. Eklabya emphasized thresholds within ecological systems as a key research need, and as befits someone working in a development context, he emphasized the development opportunities (such as REDD+) emerging from international conventions.

Jörg saw understanding of human presence in mountains via tourism, amenity migration or multi-local lifestyles as a particular research gap, and encouraged more nuanced differentiation in existing research perspectives. He also noted the risk of disconnect between researchers and mountain inhabitants. While there is a general agreement among researchers regarding the virtue of involving mountain inhabitants in the research enterprise under the heading of trans-disciplinarity, researchers may come to misrepresent groups of diverse actors, even as they attempt to validate them, with terms such as “local communities”. There is considerable diversity of interests and even conflict within mountain communities, and as such a monovalent term such as “community” or “stakeholder” fails to convey the complexity of the real world. In addition, researchers must accept that certain topics, especially regarding the economic use of mountain resources, are highly contested, and that their own views on these topics may be quite different from those held by mountain inhabitants themselves, a difference that becomes evident when truly transdisciplinary research is implemented. This situation argues for an open and unprejudiced approach to social sciences issues in mountain regions as a more fruitful basis for dialogue about contested issues.

Jill saw that researchers had a duty not only to investigate phenomena, but also to educate and to promote critical thinking among students, policy-makers and the public regarding the fundamental connected-ness of the earth system. This connectivity included a connectivity of biophysical processes, a connectivity of these processes with human, value-mediated processes, and a

connectivity of the coupled system over time.

Richard appreciated MRI’s use of the GLP figure but noted that Conference had focused very little on the third GLP theme, that of integrating analysis and models for land sustainability, which looks at how land system evolves over time and under different policies. He suggested that system evolution could form a central theme for the next Perth Conference. In addition, he mentioned the five Grand Challenges in Global Sustainability Research of ICSU - forecasting, observations, thresholds, responses and innovation - as useful indicators for where we might direct future research. Finally, he saw the Perth Conference as an expression of the great social capital among mountain researchers - an observation that I take as a compliment to our community.

Further information about the Perth Conference

View the presentations of the cited speakers on the MRI website under the title presentations:

<http://mri.scnatweb.ch/events/mri-events/global-change-and-the-world-smountains-perth-uk.html>

View the webcasts of the presentations on the MRI website:

<http://mri.scnatweb.ch/media/webcasts/>

Centre for Mountain Studies, Perth College UHI

www.perth.ac.uk/specialistcentres/cms/Pages/default.aspx

Opportunities to follow-up the Perth Conclusions: IGBP Congress, *Planet Under Pressure*

A firm conclusion emerging from the MRI Strategy Session was that the mountain community must become more active in proposing mountain-centric sessions at key scientific meetings. The IGBP Congress (info and call for session proposals below) is a very important meeting as it will feed input to the Rio+20 Sustainable Development Conference in May 2012. This particular meeting, unlike others we attend, has a defined structure, which will certainly create some constraints on the kinds of sessions chosen.

Please consider proposing mountain sessions. Some ideas for such sessions include:

- Mountains as sensitive indicators of global change;
- Lessons learned from the study of common property regimes (in mountains among other environments);

- Ecosystem services (in mountains and in other environments) as a new currency;
- Analysis of coupled human-earth systems (in mountains and elsewhere) as a route to sustainability.

Call for parallel session proposals for the 2012 IGBP Congress, *Planet Under Pressure*, March 26-29, 2012, London, UK

The *Planet Under Pressure* 2012 Scientific Organizing Committee invites proposals for parallel sessions. Deadline for submissions: 18 March 2011.

For details and online submission form see: www.planetunderpressure2012.net

Conference Outline

The four-day conference will follow this flow:

Day 1: State of the planet: the latest knowledge about the pressures on the planet;

Day 2: Options and opportunities: exchanging knowledge about ways of reducing the pressures on the planet, promoting transformative changes for a sustainable future and adapting to changes in the global system;

Day 3: Challenges to progress: clarifying what is preventing or slowing humanity from implementing potential solutions;

Day 4: Ways ahead: a vision for 2050 and beyond, and exploring new partnerships and pathways towards global sustainability.

Conference Themes

- Meeting global needs: food, energy, water and other ecosystem services
- Transforming our way of living: development pathways under global environmental change
- Governing across scales: innovative stewardship of the Earth system

“Given the mounting evidence of the sheer scale of global changes we are witnessing, the scientific community has a responsibility to urge public officials, citizens, and private firms in all countries to focus on the need for major policy changes to avoid major irreparable damage to our planet. I sincerely hope the 2012 conference will make a significant contribution to placing sustainability on everyone’s agenda.” Elinor Ostrom, 2009 Nobel Laureate Economics, Chief Scientific Advisor to the *Planet Under Pressure* conference.

On behalf of the Planet-Under-Pressure co-chairs,

— Lidia Brito and Mark Stafford Smith

Planet-Under-Pressure is organized by:

International Geosphere-Biosphere Programme, DIVERSITAS, International Human Dimensions Programme, World Climate Research Programme & their Earth System Science Partnership



Global Perspectives at the 2010 GLORIA Conference, Perth, Scotland

Colin Maher, Research Associate
University of California, White Mountain Research Station, Bishop, CA

The Fifth Annual Global Observation Research Initiative in Alpine Environments (GLORIA) conference took place on Sept. 23-26, 2010. The conference brought together GLORIA participants hailing from 34 countries (Fig. 1). Participants presented their study regions and experiences with GLORIA's unique multi-summit approach and also shared their ideas on interpreting the large data sets produced by GLORIA fieldwork. The meeting was divided into three themes: the status of GLORIA at its 10th anniversary, GLORIA data analysis and field methods, and Additional GLORIA activities.

The Status of GLORIA at its 10th Anniversary

In this segment, presenters described their GLORIA study regions (i.e., geography, plant species present, special challenges) and presented results where available in oral and poster sessions. One could not help but be amazed by the geographic extent of GLORIA: there are study regions on nearly every continent. The one

continent not yet represented, Africa, will soon join the ranks as sites in the Atlas Mountains in Morocco are in the setup phase.

In many of the study regions, only the initial survey had been completed, though a few had results to present from the first resurvey. A pattern seemed to be emerging from widely dispersed study regions: increased plant species richness was observed in European sites as well as in the Western US. Although these results are preliminary (they are based on only two data points), they emphasize that the power of this simple approach lies in the geographic spread of study regions.

GLORIA Data Analysis and Field Methods

In these sessions, the participants shared their ideas on how to analyze the incoming data sets in workshop groups; we discussed the applications of species functional traits, climatic zones and slope approaches.



Figure 1. Participants at the Fifth Annual GLORIA Conference in Perth, Scotland (photo, C. Maher).



Figure 2. Field trip to the Cairngorms, Scotland, a GLORIA target region. A. Overview, B. GLORIA group on the summit (photos, C. Maher).

We also openly discussed and voted on what refinements should be made to the official GLORIA methodology. After the presentations of the study regions, everyone had a very good sense of what challenges each GLORIA team faced using the methodology (i.e., 5 day treks to summits, rocky substrates, high species diversity, etc.). This made for a very productive session and resulted in an elegant set of obligatory and optional methods.

Additional GLORIA Activities

Nearly all GLORIA regions engage in supplemental activities that provide a sense of climate change effects in these mountain regions beyond the plant communities. These activities include insect surveys, soil studies, and ethnobotanic and socio-economic studies. Although these approaches are not comparable between regions, they promise to make some very interesting studies at the local level.

Conclusion

GLORIA central at the University of Vienna in Austria did a great job of organizing a group of people from diverse countries and with differing views on how GLORIA should proceed. On the final day of the conference, we hiked out to a GLORIA study region in the Cairngorms (Allt a' Mharchaidh catchment, Fig. 2). The meeting ended with a great sense of cooperation, accomplishment and of the tantalizing possibilities of collaborative studies using the immense GLORIA data set to understand climate change impacts on mountain ecosystems.

For more information:

GLORIA International Program: www.gloria.ac.at/

GLORIA North American Chapter: www.fs.fed.us/psw/cirmount/wkgrps/gloria/

The GLORIA Plant Functional Traits Working Group

Martha E. Apple

Associate Professor, Department of Biological Sciences
Montana Tech of the University of Montana, Butte, Montana 59701

The GLORIA (Global Research Initiative in Alpine Environments) conference was held in Perth, Scotland September 23-26, 2010, and the GLORIA Plant Functional Traits Working Group formed as a part of this wonderfully informal yet intensive gathering of GLORIA researchers from around the world. Participants in the GLORIA Plant Functional Traits Working Group, led by Jan Dick, are interested in adding information on the functional traits of plants to the GLORIA database, while remaining under the GLORIA aegis of inexpensive, quick, and scientifically sound research.

Plants can be classified taxonomically and according to their myriad and diverse functional traits (Cornelissen et al. 2003). Plant functional traits include aspects of physiology, life history, morphology, phenology and structure/function relationships. Examples of these traits are Raunkiaer growth form, life span, height, flower type, leaf morphology, presence of rhizomes, clonality, seed mass, and mode of seed dispersal (Fig. 1). Some plant functional traits, such as flower type and leaf morphology, are relatively easy to define. Specific leaf area, leaf dry matter content, and sensitivity of leaves to frost are more difficult to define. Below-ground traits include specific root length, root depth, and mycorrhizal status.

Cushion plants with small, xeromorphic leaves (for example, *Eritrichium nanum*) and geophytic plants arising from bulbs or other subterranean structures (for example, *Lloydia serotina*) are intriguing life forms of alpine plants. The vast morphological differences between these two species no doubt influence their functionality, and it is within the realm of possibility that these two species may in turn have vastly different responses to changing climatic conditions or other drastic alterations in their habitats.

Plant functional traits can extend to factors that pertain to plant life histories. The phenology of flowering, abiotic and biotic pollination scenarios, and seed morphology, dispersal mechanisms, and germination are important factors in plant life cycles. These types of plant functional traits can be very complex since they often do not depend solely on the plants but also on abiotic factors and plant-animal interactions.



Figure 1. The linear leaves of *Carex* represent an example of a plant functional trait, as discussed on a field trip to the Cairngorms GLORIA site in Scotland (photo, M. Apple).

Plant functional traits may be used as predictors of responses to climate change and the addition of these traits to the GLORIA database will be valuable in predicting and verifying changes in plant species presence, distribution, abundance, phenology, and position with respect to altitude and slope.

The Plant Functional Traits Working Group is in close communication with researchers at the GLORIA coordinating office in Vienna, Austria and we are working toward incorporating plant functional traits into the GLORIA database, quite possibly with linkages to species lists and other data for each GLORIA site (Pauli et al. 2010). However, we must devise a plan to obtain the data while honoring the theme of quick and approachable fieldwork. We propose a core group of the more easily determined traits along with a recommended group of more intensively determined traits. A great deal of this data already exists in Jepson's Manual (1993), the USDA Plants Database, plants.usda.gov, in photographs of the GLORIA sub-summits, and in the literature as a whole. It would be fairly straightforward for researchers to augment GLORIA species lists by adding onto spreadsheets to denote easily recognizable categorical traits such as whether a plant was a tree, shrub, or forb, evergreen or deciduous, and so on. For less well-known plant functional traits, gathering field data would lead to more knowledge on site-specific variations in these traits (Fig 2).



Figure 2. This rock, covered with lichens, *Carex*, heather, and other plants, shows another example of plant functional adaptations to the tundra environment that was obvious on the GLORIA hike to the Allt a' Mharcaidh Catchment in Cairngorms National Park (photo, M. Apple).

While all participants in the Plant Functional Traits Working Group at the GLORIA conference in Perth, Scotland were in agreement to move forward with this idea, we are currently in discussion on exactly how to set up this addition to the GLORIA database, and we welcome your suggestions, ideas and comments.

North American contacts include Lindsey Bengtson at USGS NOROCK, (lbengtson@usgs.gov), and Martha Apple at Montana Tech (mapple@mtech.edu). The organizer and main overall contact for the GLORIA Plant Functional Traits Working Group is Jan Dick (jand@ceh.ac.uk) at the Centre for Ecology and Hydrology, Edinburgh, Scotland.

References

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Pauli H., M. Gottfried, G. Grabherr & partners from the GLORIA Europe Network. 2010. Climate change and Europe's alpine plant diversity: the GLORIA long-term observation network (Box 8.3) In: *Europe's ecological backbone: recognizing the true value of our mountains*, pp. 155-157. EEA Report No 6/2010, European Environment Agency, Copenhagen.

CIRMOUNT Meanderings

A round-up of ongoing within the CIRMOUNT community

With changes afoot among the CIRMOUNT coordinators, I thought to ask the outgoing group to reflect on what CIRMOUNT did well in its first years; to the incoming coordinators, I asked what CIRMOUNT might skillfully achieve in coming years. I captured a few of their comments here – Ed. (cim)

Stepping into an advisory role...

Dan Cayan Before CIRMOUNT, the mountain research community in western North America was only connected in ad hoc fashion. It was recognized that climate changes could have especially harsh consequences in high gradient mountain settings, but there were few if any syntheses across issues and across the mountain landscape. Clearly, CIRMOUNT has wired a stronger network linking mountain researchers and has provided an invaluable forum to discuss issues. It is particularly important that CIRMOUNT is providing a voice for cohorts of young researchers. Through efforts such as “Mapping New Terrain”, CIRMOUNT is laying out mountain issues more comprehensively, not only for the researchers themselves, but to inform and engage the community who use and value the many resources that mountain habitats provide. These achievements are remarkable considering the lack of dedicated budget that has been available to carry this out, and they are an example of the potential of an interdisciplinary group when goals are set and commitments are sustained. There remains much to do. Early on, CIRMOUNT laid out the imperative for better observations and more integration --we have only begun to advance on these goals.

Lisa Graumlich CIRMOUNT was a major force in creating social capital linking scientists and resource managers concerned about climate change impacts. Social capital is hard won—it takes years of building trust and community. And, it’s critical for creating a dialog that leads to truly innovative concepts and perceptions that lead in turn to meaningful shifts in policies and practices; **Malcolm Hughes** CIRMOUNT has really helped surmount (!) the dispersed, fragmented nature of research on mountain environments. Much remains to be done, but the very existence of such a focal point, the newsletter and the MTNCLIM meetings has gone a long way towards pulling the various strands together. For me, the single best aspect has been the student presentations at MTNCLIM meetings - smart young people doing cool stuff on vital topics. **Tom Swetnam** CIRMOUNT has been a tremendous “nexus”; a great success in bringing together and engaging scientists and managers who care about the West.

And joining the coordinators group...

Andy Bunn I hope that we continue to organize top mountain researchers across the sciences and encourage work on applied projects that will help managers make good decisions. I also hope that we develop educational materials that engage the public on why mountains matter. **Gregg Garfin** CIRMOUNT might attempt to do some of the things that funded research coordination networks do, such as: develop policy white papers, submit research priority agendas to funding agencies, and foster collaborative grant-writing among CIRMOUNT participants. CIRMOUNT might also broaden the scope of its meeting coordination, for example, to propose sessions at the high profile annual meeting of the AAAS. Another potential activity is for CIRMOUNT to draw up talking points on mountain climate-environment-society issues to distribute to colleagues, NGOs, and natural resources extension agents. **Jeff Hicke** CIRMOUNT should continue to organize interactions for scientists interested in climate change in mountain regions, and continue to engage with resource managers to provide useful information on this topic. **Jeremy Littell** CIRMOUNT should continue to do what it already does well - facilitate collaborative research in mountain systems (ecosystems, human systems, and coupled geophysical systems) and develop communication of that research and its usefulness to stakeholders in mountain environments. But we need to do more and do it more effectively - there is a broader audience out there than the scientific and decision-making communities we have focused on to date, and mountain systems have a unique potential to motivate public interest in science at a time when the role of science in public discourse is declining. I think we need to further engage decision-makers and the public to make sure our curiosity-driven research is most useful to and used by those who value mountain systems. **Christina Tague** The body of science on climate change impacts in mountain environments grows daily. At the same time we are increasingly seeing practical applications of that research as resource managers and others begin to pursue adaptation options. I think CIRMOUNT can play an important role in helping to highlight key findings and activities as they emerge. To do

that I see CIRMOUNT utilizing network-information sharing technologies - of course the website, but also blogs, participatory community networks, and perhaps experimenting with ways to

identify high-quality synthesis products, including reviews but also products like teaching and outreach materials that help to make sense of the breadth of available information.

Announcements

Send contributions for posting in this section to cmillar@fs.fed.us

- For the 7th year, CIRMOUNT sponsored a session at the Fall Meeting of the American Geophysical Sciences Union. The 2010 session was entitled, Ecosystem Responses to Fine-Scale Climate Variability in Mountainous Terrain, convened by Greg Greenwood, Jeff Hicke, Connie Millar, Christina Tague, and Chris van de Ven. Presentations from the oral and poster sessions are available on the CIRMOUNT website: www.fs.fed.us/psw/cirmount/meetings/agu/agu2010.shtml
- MtnClim 2010 meeting archive (June 7-10, 2010, HJ Andrews Forest, OR). Presentations at: www.fs.fed.us/psw/mtnclim/
- CIRMOUNT meeting archive website (for all events): www.fs.fed.us/psw/cirmount/meetings/archives.shtml
- National Workshop on Climates and Forests; Planning Tools and Perspectives on Adaptation and Mitigation Options, May 16-18, 2011 Northern Arizona University, Flagstaff, AZ. www.safnet.org/natworkshop11/index.cfm
- Fourth Interagency Conference on Research in the Watersheds; Observing, Studying, and Managing for Change. September 26-30, 2011, Fairbanks, Alaska. www.hydrologic-science.org/icrw/
- Open Science Conference: Climate Research in Service to Society. World Climate Research Program. October 24-28, 2011, Denver, CO USA. www.wcrp-climate.org/conference2011
- 2012 IGBP Congress, "Planet Under Pressure", March 26-29, 2012, London, UK, www.planetunderpressure2012.net (more details about mountain science opportunities at this major conference on page 22)

Upcoming Meetings:

- Pacific Climate (PACCLIM) Workshop, March 6-9, 2011, Asilomar Conference Center, Pacific Grove, CA. Contact: Scott Starratt, USGS, sstarrat@usgs.gov
- Climate Change Impacts on Extreme Events, March 21-23, 2011, San Diego, CA. A workshop sponsored by the Western Governors' Association, Western States Water Council, and California Department of Water Resources. Contact: jgroat@wswc.utah.gov

Mountain Visions

From the palettes of our CIRMOUNT community

Robert Coats is a research hydrologist with Hydroikos Ltd. in Berkeley, CA. Bob has been researching climatic, hydrologic, and ecological processes in the Lake Tahoe Basin for over 40 years. He has been writing poetry for equally as long. A native Californian, Bob spent summers as a teenager in northeastern Nevada, where his father was engaged in field work for the USGS. His poems have appeared in Orion, Zone 3, Windfall, The Acorn, and the Pudding House anthology Fresh Water: Poems from the Rivers, Lakes and Streams. – Eds.

COPPER BASIN, NEVADA, 1960

Through fields of mule ears,
sagebrush under a cupric sky
I rode with my father down a rough track,
deep into Copper Basin.

He parked the Jeep, showed me
on an aerial photo where we'd meet,
then set off to sample rocks,
while I headed downstream to fish.

Soon the wide valley narrowed.
The creek entered a gorge,
cut through rust-red quartzite to form
bright cascades, deep pools where trout sculled.

Here, no sign of cows, cowboys,
no sheepherders, hunters, nor prospectors.
Only aspen, willow thickets, debris jams,
walls of sheer cliff and talus.

The day grew hot. I tied my shirt
around my waist, plunged
my head into the creek,
gulped the water, cold and sweet.

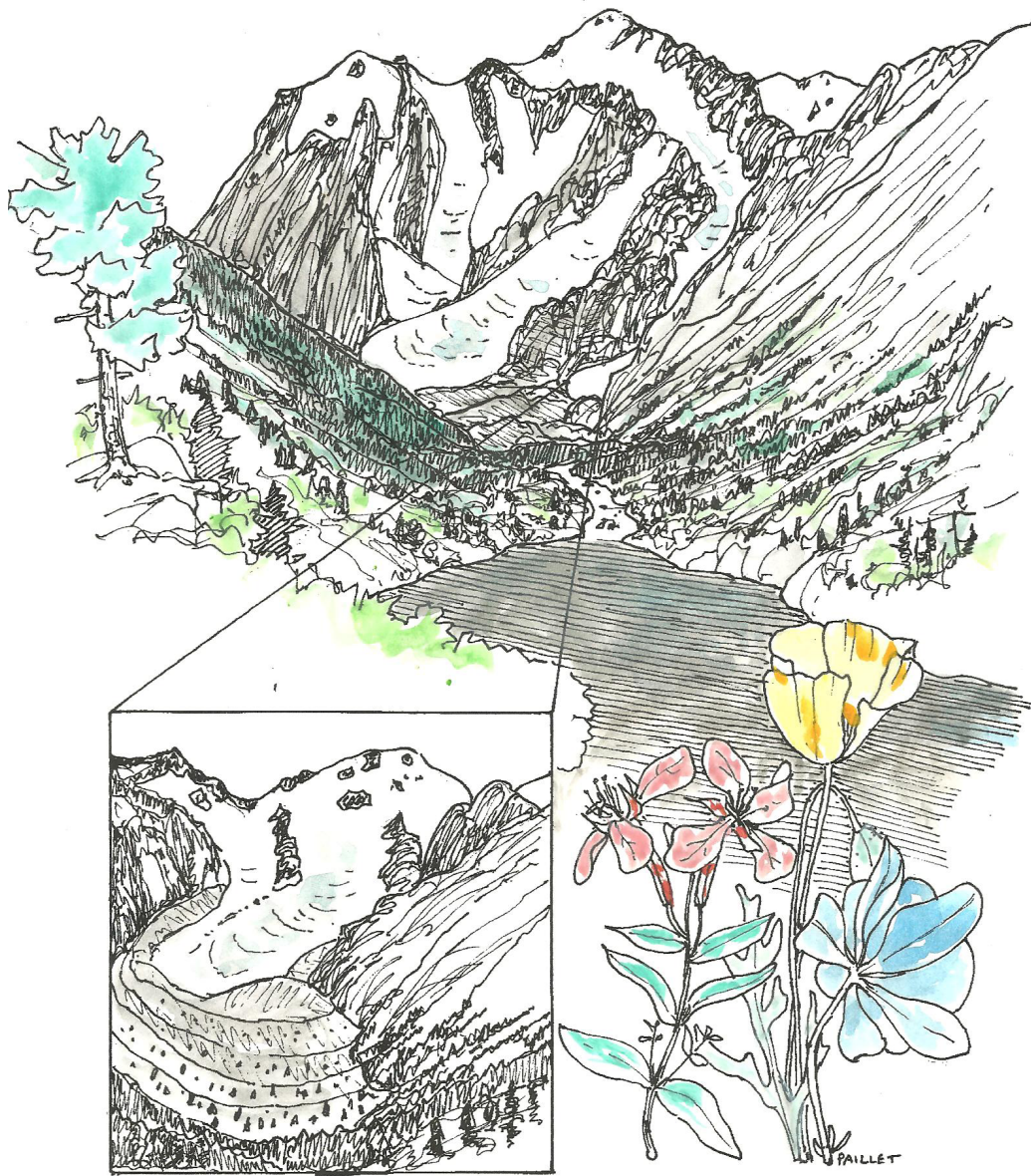
There, deep in the mountain's heart
I saw on the streambed--
swept clean of dark sand and gravel--
a ledge of pure white marble.

—Robert Coats, May 2010



Copper Basin and the Jarbidge Range, northern Nevada, from the crest of the Copper Mountains (photo, C. Millar).

I met Fred Paillet, then a USGS geophysicist, years ago at a PACLIM conference in Pacific Grove, California. In corresponding with him subsequently, I learned that Fred is both an astute observer of mountain ecosystems and an accomplished artist. I fell in love with the sketches Fred would send me from his field notebook. Now retired, Fred remains an explorer of mountains worldwide, and continues to pursue interests in hydrology, paleoclimate, and botany. He is associated with the Gesociences Department at the University of Arkansas, and can be found hanging out at the local Tree Ring Laboratory. – Ed. (cim)



This diagram shows Shavlinsky Lake and surrounding peaks in the headwaters of the Chuyah River in the Altai Mountains of Siberia as they appeared in July, 2002. The inset diagram shows a small glacier (barely visible in the larger view) with a series of recently abandoned terminal moraines, each covered by a scattered population of larch of progressively increasing size with distance from the terminus. The series of moraines and the progressive ages of the trees growing on them demonstrate a prolonged period of steady retreat. In this view, tree line is located at about 2290 m in elevation and the most distant peaks extend

above 4000 m. The forest is composed almost exclusively of larch (*Larix sibirica*), with local populations of stone pine (*Pinus cembra* var *sibirica*) and spruce (*Picea sibirica*). The abundant wildflowers in local meadows include most of the familiar flowers from the American arctic such as dwarf fireweed (*Epilobium latifolia*) and arctic poppy (*Papaver lapponicum*), and other Asian endemics, such as a giant-flowered spurless columbine (*Aquilegia sibirica*).

—Fred Paillet, 2011



(photo, J. Hicke)

High in the Range of Light
the wind hones little knives of ozone
on cornice, on sheer granite cliff.
A coyote wakes, sniffs the new air,
sets out into a crystalline world
of solitude.

From: "When the Drought Broke"
Bob Coats, 1995