

Mountain Views

Chronicles of the Consortium for Integrated
Climate Research in Western Mountains
CIRMOUNT



Informing the Mountain Research Community

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Ice calving from the terminus cliffs of Canada Glacier, McMurdo Dry Valley, Antarctica. Photo: Hassan Basagic.

Front Cover: Snow on Canisp and Suilven, Lochinver [Scotland]. © Amy Holden (Woolvin)

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Back Cover: Old Man of Storr from Applecross Peninsula [Scotland]. © Amy Holden (Woolvin)

Read about the contributing artists on page 97.

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Larry Ruth
Amy Holden (Woolvin)

Welcome to *Mountain Views*! Herein you can read summaries of recent journal articles on mountain-climate related research, digests of new mountain-research projects, updates from ongoing programs, and a sampler of perspectives on the role of science in mountain culture, from personal research experiences to art. In that *Mountain Views* serves the CIRMOUNT community, the focus is on western North American mountains. Increasingly, however, we seek to highlight related research from mountain regions worldwide and international mountain-science programs.

You might notice several things different about this issue of *Mountain Views*. Most importantly, as part of stretching beyond North America, we teamed up with the international Mountain Research Initiative (MRI: <http://mri.scnatweb.ch/en/>) to co-produce this issue of *Mountain Views*. Erin Gleeson of MRI served as co-editor, rounding up articles that synthesize the October mountain-climate congress in Perth, Scotland, *Mountains of our Future Earth*, which we highlight throughout this issue. Erin also brought together a section featuring projects that promote MRI's ambitious goal to integrate and coordinate mountain research worldwide around issues of highest priority.

Our *Brevia* section remains the core of *Mountain Views*—anchoring our intent to feature new and basic research related to mountain climates. Deepening drought has emerged as a pervasive challenge to mountain ecosystems worldwide. We include summaries of two new research papers, one that addresses the global impacts of drought to forests, and another that places the current drought in historic perspective. With increasing warmth and lessening snowpacks, knowledge about snow retention is of high importance, and we include a summary

of a new article investigating relationships between snow duration and forest cover.

As the world community culminates what appears with high probability to be the warmest year on instrumental record, we pay tribute to those iconic mountain sentinels of climate change: glaciers. We feature a section containing articles on glaciers in western North America, both research and research history; two syntheses relating to glaciers from the Perth III conference; a *First Person* experience of glacial research in Antarctica; and photography and artistry of glaciers by CIRMOUNT scientists.

In addition to content and geographic stretch, other changes to *Mountain Views* regard presentation. In that we feature more than news, we changed the name of our periodical to *Mountain Views Chronicle*, hoping that this captures both the intent to communicate science and the spirit of mountain adventure. We also gave the chronicle a facelift, with the goal to make form follow function, and to improve readability as well as professional appearance.

To you and your families we send best wishes for the holiday season. We hope to see friends at the Annual Fall Meeting of the American Geophysical Union in San Francisco in December, at *MtnClim 2016* next October, and in the mountains of our neighborhoods during times between.

Connie Millar, Editor



Erin Gleeson, Co-Editor



Perth, Scotland with the River Tay, where the *Mountains of our Future Earth* Conference convened in October 2015.

Harald Bugmann

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I am a forest ecologist. Therefore, I go to meetings that deal with forest science, such as those hosted by the International Union of Forest Research Organizations (IUFRO), or with general ecological topics, such as those hosted by the Ecological Society of America (ESA) or the German Ecology Association (GfÖ). There, I feel cozy because I am

familiar with many names on the program, I have at least some idea about the contents that lure behind presentation titles, and I keep bumping into people that I have known since a long time. Essentially, I have the opportunity to meet a considerable fraction of the key people in the respective disciplines, and I can expand my network of disciplinary scientific contacts quite well. We share the same (or at least a very similar) vocabulary and, probably even more importantly, similar points of view about science and the key questions to be addressed in our research. I learn a lot that has direct bearing on my own research, and I return home with a general feeling of satisfaction.

In 2005, when I flew to Edinburgh to attend the first conference of what is now known as the series “Perth I-III”, I was definitely stepping out of my comfort zone. Or should I say, flying? OK, I had been involved in the interdisciplinary research project GLOCHAMORE (acronym for “Global Change in Mountain Regions”) that was funded by the European Union and actually gave rise to the “Perth I” conference. Thus GLOCHAMORE and my work for the Mountain Research Initiative had prepared me for interdisciplinarity to some extent. However, the “Perth I” experience was quite different because of its breadth and magnitude. So I happened to arrive in Perth. Looking at the program, it was very encouraging that 210 scientists were attending the event, and we obviously had achieved global coverage as these people were coming from 41 countries and six continents. Wow! However, it appeared to be quite discouraging that I knew relatively few names. Looking at the titles of the

presentations, I even shivered because they contained many mysterious phrases whose meanings were undecipherable to me. Most of the key forest scientists and ecologists were absent from this event. Thus, what was I to do here?

In the following days, I discovered that this conference was different for very good reasons – I listened to presentations and looked at posters that made me aware of the full breadth of mountain research and the full complexity of mountain livelihoods – sure I could have and maybe even should have ‘known’ all of this before. But ‘knowing’ and truly experiencing are different things. This was a full week of interdisciplinary listening, talking, learning. I was exposed to an enormous amount of stuff that I would never have had a chance to grasp at meetings like those organized by IUFRO, ESA, or GfÖ. I kept bumping into people that I did not know and that were working in ‘remote’ disciplines, but we started talking and very many of these contacts turned out to be quite fruitful; at the very least, they strongly expanded my horizon. I had the chance of practicing interdisciplinarity on a daily basis; and – luckily – the lack of a disciplinary “bracket” was replaced fully by the cozy “mountain” bracket. I returned home with a general feeling of satisfaction.

I happily went to many more disciplinary meetings after 2005, organized by IUFRO, ESA, GfÖ and the like – but towards 2010 it was high time for a second big meeting outside my comfort zone! I had the impression that this second conference was an even bigger success than the first one, and soon after my return home I started to look forward to “Perth III” in October 2015.

I am convinced that it is the right balance between interdisciplinary and disciplinary meetings (and collaborations) that can and will bring mountain research forward. I feel that a new breed of ‘mountain researchers’ is being formed by the Perth conference series, along with efforts such as those of the Mountain Research Initiative and other organizations. The members of this community need their disciplinary ‘roots’ and clearly must remain in close contact with their disciplinary colleagues who are not working on mountain issues. However, we also need a regular venue to meet in an interdisciplinary context because the future of mountain regions cannot be

addressed from a disciplinary perspective alone – land parcels are highly connected in a complex topography, and so are the disciplines that are required to understand and manage mountain systems.

For the coming few years, I will happily attend many more disciplinary (and some interdisciplinary) meetings. However I know already now that I will soon be looking forward to “Perth IV” in 2020!



Glen Doll, Cairngorm Mountains, Scotland; destination of one of the field trips during the Perth III conference. Photo: Connie Millar.

Quantifying Snow Duration under Diverse Forest Canopies

Susan E. Dickerson-Lange

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Dickerson-Lange, S.E., J.A. Lutz, K.A. Martin, M.S. Raleigh, R. Gersonde, and J.D. Lundquist. 2015a. Evaluating observational methods to quantify snow duration under diverse forest canopies. Water Resources Research 15:1203–1224.

Dickerson-Lange, S.E., J.A. Lutz, R. Gersonde, K.A. Martin, J.E. Forsyth, and J.D. Lundquist. 2015b. Observations of distributed snow depth and snow duration within diverse forest structures in a maritime mountain watershed. Water Resources Research. DOI 10.1002/2015WR017873

The snowpack that accumulates and persists within forests represents a large portion of the water balance in mountain watersheds, with forests covering almost 40% of the seasonally snow-covered regions in North America. Forests are a key influence on how much snow is stored in the mountains and when the snow melts because forest cover reduces snow accumulation via canopy interception and modifies melting processes. However, the overall effect of forests can be to delay or accelerate snow disappearance timing relative to open areas (Lundquist et al. 2013). The resulting spatial distribution of snow duration (i.e., fractional snow-covered area, or fSCA) is a key variable for ecological, hydrological and land-atmosphere interactions, but forest snowpack is only sparsely observed and accurately representing forest-snow processes in hydrologic models is problematic (Essery et al. 2009).

Both the magnitude and direction of forest influence on individual snow processes like accumulation and melting vary with climate (Lundquist et al. 2013), forest characteristics (Kittredge 1953), and topographic position (Ellis et al. 2012). Observations of forest snowpack that sample the range of forest-snow influences are needed for improved process understanding and model testing. However, operational snow networks are located primarily in forest clearings and optical remote sensing cannot see through tree canopies to detect forest snowpack. As a result, there is currently no feasible substitute for ground observations. Thus, we assessed observational strategies to quantify under-canopy snow duration (Dickerson-Lange et al. 2015a), with an ultimate goal to improve understanding and prediction of forest-snow processes.

Improved prediction of forest effects on snow is of particular interest in the context of changing climate and forests. As the climate warms, snowmelt contributions to rivers are generally predicted to decline because the snow level will rise and less precipitation will fall as snow (Elsner et al. 2010). In addition, warmer spring temperatures will cause the timing of maximum spring melt to shift earlier in the year, resulting in lower flows and higher stream temperatures during the late summer. Complicating these projected changes are current and future land use changes, including development, logging, and shifts in management policies, as well as increasing forest disturbance (Barbero et al. 2015). Vegetation characteristics have the potential to amplify or dampen climate change effects because snow processes depend on forest characteristics as well as climate. The presence of forest cover can delay (Rutter et al. 2009, Thyer et al. 2004) or accelerate (Storck et al. 2002, Dickerson-Lange et al. 2015a) snow disappearance timing relative to open areas. Large-scale experiments on optimal forest management for water yield were conducted beginning in the early 1900s with mixed results (Bosch and Hewlett 1982), but the capability to maximize snow retention on the landscape requires improved understanding of forest-snow processes.

Comparing Observational Strategies

To support future observational studies of snow duration, we assessed the effectiveness of different strategies to observe snow-covered area under forests (Dickerson-Lange et al. 2015a). Our study location was the Cedar River Municipal Watershed, located on the western slopes of the Cascade Range, approximately 50 km east of Seattle, Washington. We simultaneously deployed fiber-optic cable, stand-alone ground temperature sensors, and time-lapse digital cameras (Fig. 1) in three diverse forest treatments: control second-growth forest, thinned forest, and forest gaps (one tree height in diameter) (Fig. 2).

We derived fractional snow-covered area and snow duration metrics, such as the number of snow-covered days, from the co-located instruments to assess optimal spatial resolution and sampling configuration, and snow duration differences between forest treatments. Each instrument determines point-scale snow presence in a different way. The iButton and fiber-optic cable

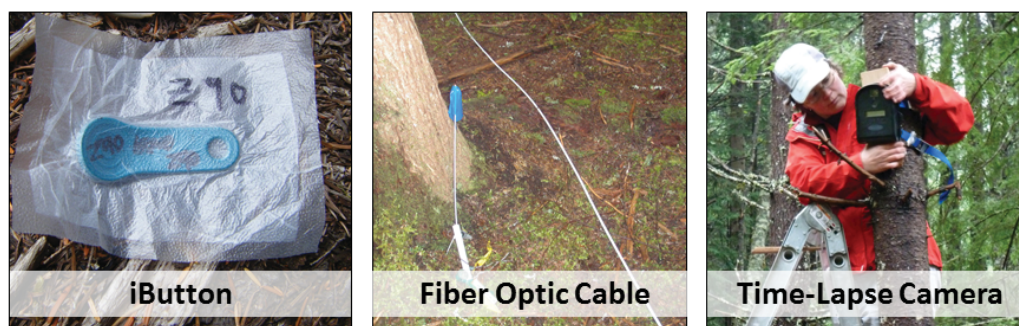


Figure 1. At intensive study plots we co-located three instruments to detect snow duration: stand-alone temperature sensors (iButtons), a fiber optic cable (FOC) that observes distributed ground temperature (from which snow presence is inferred), and time-lapse cameras (from which snow cover can be quantified).

are both temperature sensors, but the iButton is shallowly buried whereas the fiber-optic cable rests on top of the ground surface (Fig. 3a). Snow presence is inferred from the lack of a diurnal temperature fluctuation recorded by both instruments (Lundquist and Lott 2008, Raleigh et al. 2013; Figs. 3b and 3c). The time-lapse camera records sub-daily images of snow cover, from which fSCA can be quantified on a pixel-by-pixel basis.

By comparing results from co-located instruments, we found that the three methods agreed on snow disappearance day within 0-5 days, and similarly characterized the time series of fSCA (Figs. 3d – 3f). Based on a practical assessment, we recommend deployment of grids of ground temperature sensors or a minimum of two cameras per experimental unit (note that challenges and considerations related to the successful deployment of each type of sensor, from a bear biting the fiber-optic cable to waterproof iButton cases, are discussed in detail in the electronic

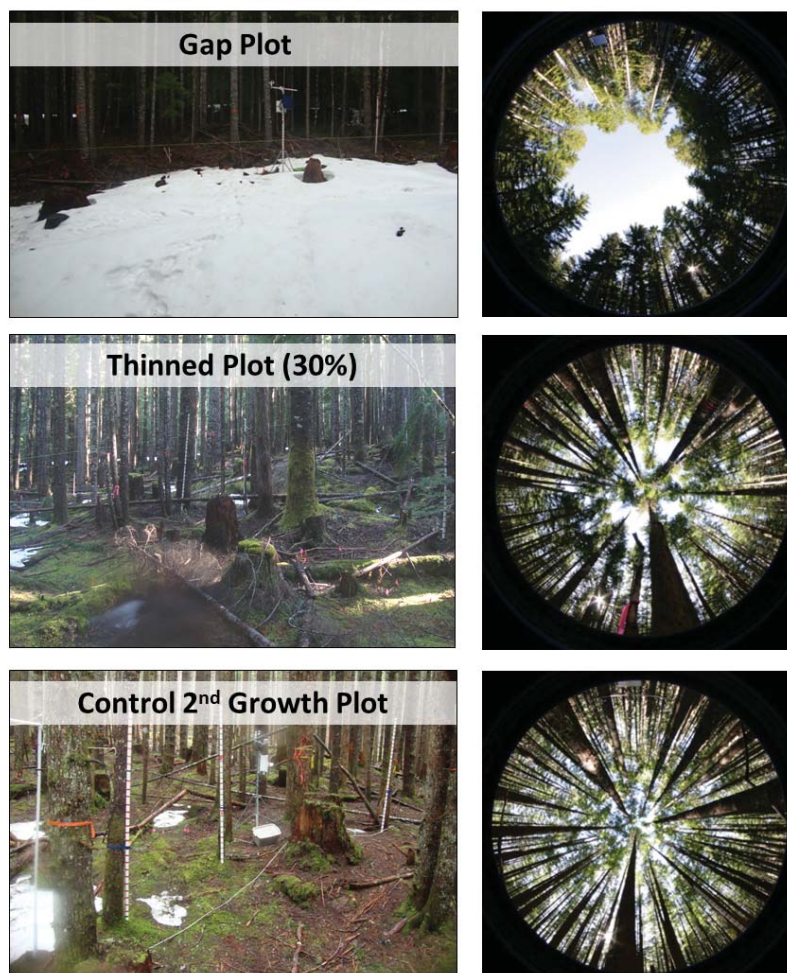


Figure 2. The study site included multiple 40 m × 40 m experimental plots subject to three silvicultural forest treatments: gap plots with a circular gap approximately 20 m in diameter cut into the middle of the plot, thinned plots with ~30% of the basal area removed, and control 2nd growth plots. Site photographs are all from 4 May 2012, and upward-pointing hemispherical photos were taken from the center of each plot.

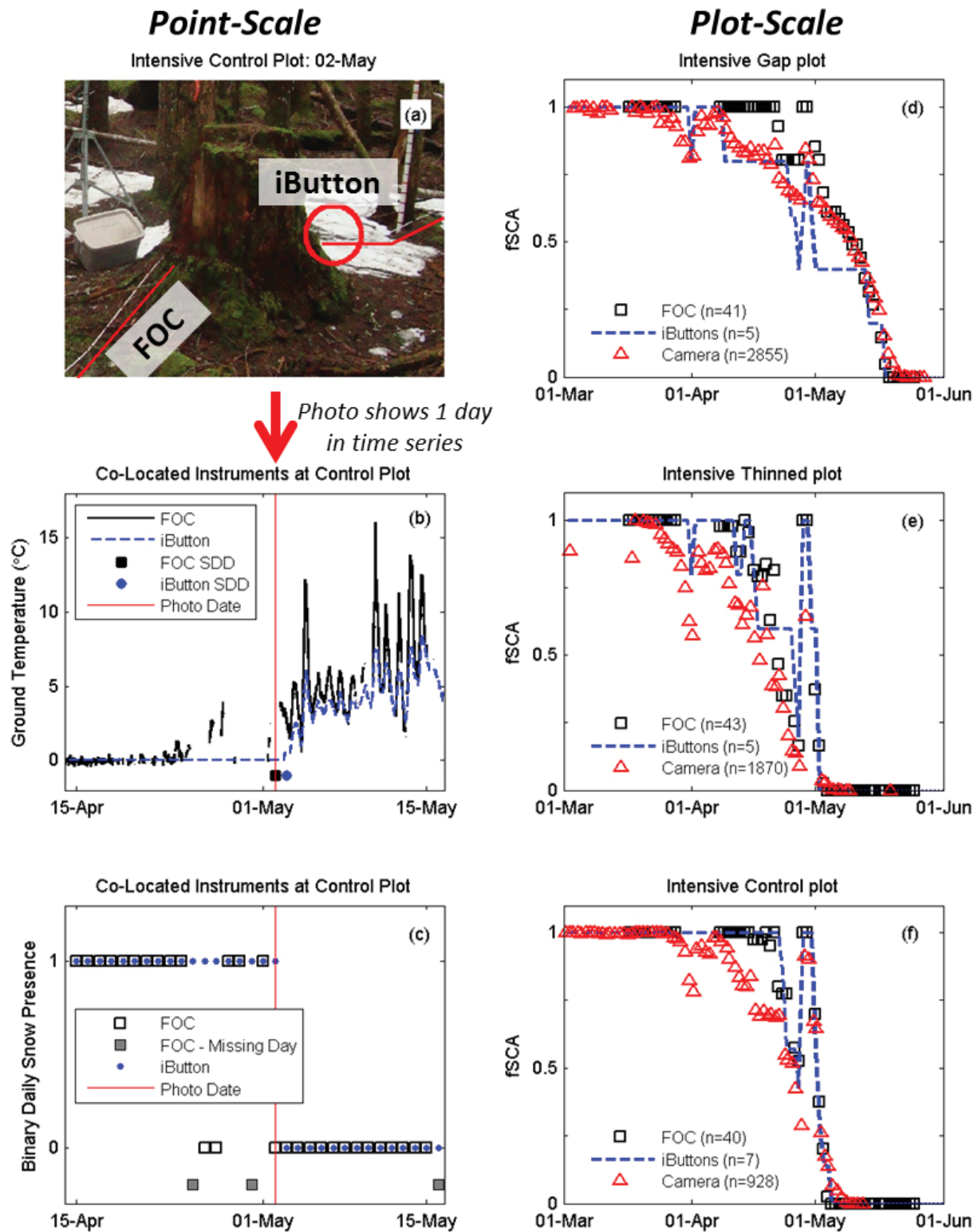


Figure 3. Point comparison of the (a) location, (b) ground temperature, and (c) snow presence observed by an iButton and the fiber optic cable during water year 2011. Plot-scale comparison of fractional snow-covered area (fSCA) at each plot (d-f) derived from point locations along a fiber-optic cable (FOC), a grid of iButtons, and a single time-lapse camera. Legends indicate the number of point observations used to compute fSCA.

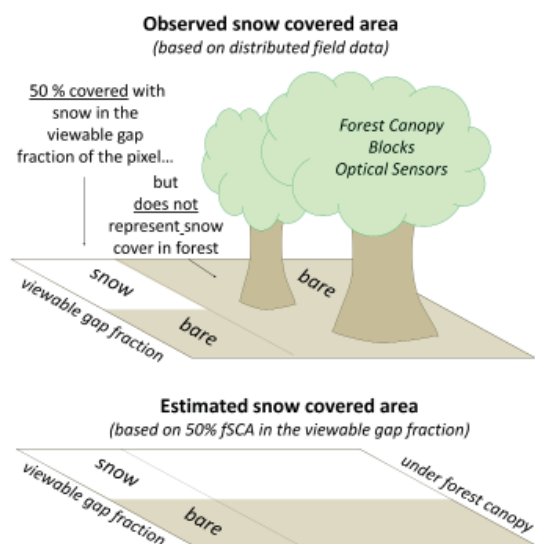


Figure 4. Cartoon of fSCA in a grid element (i.e., pixel) based on observations, where fSCA is 50% in the open when snow has completely disappeared under the forest (top), and based on the assumption commonly used for remotely sensed snow-covered area, in which fSCA in the viewable gap fraction is equal to fSCA under the forest.

supplement to Dickerson-Lange et al., 2015a). Based on Monte Carlo experiments that used observational data we recommend a maximum spacing for temperature sensors of 6 m to achieve a 95% confidence interval of ± 3 days around the mean snow duration.

Snow Lasts Longer in the Open at These Sites (But Not Everywhere)

Final snow disappearance was approximately two weeks longer in the gap (i.e., open) plots relative to the forested plots across two elevation bands and two winters of observation at this relatively warm, maritime field site. There was no detectable effect on snow disappearance timing from a 30% reduction in basal area in the thinned plots. The differential snow disappearance timing values observed at these sites are in the opposite direction to the difference observed at colder, continental sites where snow has been observed to persist longer in the forest. In global synthesis of paired-forest snow studies (Lundquist et al. 2013), we found that winter climate is a first-order predictor of whether the net effect of forest cover is to accelerate or delay snow disappearance. In addition, a difference of two weeks between land cover types is an end point on the range of differential snow disappearance timing from forest-snow observations worldwide. Thus, improved understanding of forest-snow dynamics in warmer climate regimes may be critically important for assessing potential combined effects

of forest change and climate change. Under warmer winter climate conditions, or in anomalously warm years, forest-snow interactions in colder, continental locations could shift to become more similar to the forest influences observed in warmer sites today.

The observed difference between snow disappearance timing also highlights the need for ground observations to improve estimates of fSCA derived from optical remote sensing products. Remotely sensed snow-cover products, such as those derived from MODIS and Landsat, estimate fSCA under forest canopies based on observed fSCA in the open area, or the viewable gap fraction (Durand et al. 2008, Liu et al. 2008). For example, if an optical sensor detects 50% fSCA for the open portion of a grid element, fSCA under the forest is also assumed to be 50%, which for this site would result in a substantial overestimate of snow cover (Fig. 4).

Scaling Up From Experimental Plots

Snow lasting longer in a few experimental gaps in one watershed is an interesting result, but to develop a forest management strategy to maximize snow retention, forest-snow dynamics must be estimated at larger spatial scale. On-going work in this area includes continued data collection in the Cedar River Watershed (four years of forest, snow, and meteorological data [Dickerson-Lange et al. 2015b] are publicly available for analyses and model testing at <http://depts.washington.edu/mtnhydr/data/cedar.shtml>), as well as additional data collection using time-lapse cameras and measurement poles at the crest of the Cascades. Preliminary results suggest that snow consistently persists longer in the open as compared to the forest across a range of elevations and years, but that this difference may be diminished in very sparse forests. These data are also included in a collaborative effort with Oregon State University and University of Idaho to complete empirical analysis of forest-snow observations across the region and improve process understanding in a range of climate, forest, and topographic conditions. At a smaller spatial scale, we are also relating LiDAR-derived forest canopy metrics to point snow observations in order to ultimately improve representation of forest characteristics in distributed models.

A clear understanding of the future water resources in mountainous regions requires the clarification of the mechanisms and timescales of both land cover and climate effects on snow processes. Through observations and modeling, we are working to constrain the sensitivity of snow processes to forest characteristics and climate. Ultimately, we aim to improve understanding of future hydrologic impacts and test possible adaptation strategies.

Collaborators and coauthors on this project include: Jessica Lundquist, Jim Lutz, Kael Martin, Mark Raleigh, and Rolf Gersonde. Funding was provided by the National Science Foundation (CBET-0931780) and an NSF Engineering Directorate Graduate Research Diversity Supplement (GRDS). Collaborators on continuing forest-snow work additionally include Anne Nolin at Oregon State University and Tim Link at the University of Idaho, and funding is provided by the Department of the Interior Northwest Climate Science Center (NW CSC) through Cooperative Agreement GS297A from the United States Geological Survey (USGS). We thank Seattle Public Utilities for access to the watershed and continued support of this research. Four years of forest, snow, and meteorological data for the Cedar River Watershed, WA are publicly available at <http://depts.washington.edu/mtnhydr/data/>.

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On Underestimation of Global Vulnerability to Tree Mortality and Forest Die-Off from Hotter Drought in the Anthropocene

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Allen, C.D., D.D. Breshears, and N.G. McDowell. 2015. On underestimation of global vulnerability to tree mortality and forest die-off from hotter drought in the Anthropocene. *Ecosphere* 68:129. doi.org/10.1890/ES15-00203.1.

Patterns, mechanisms, projections, and consequences of tree mortality and associated broad-scale forest die-off due to drought accompanied by warmer temperatures—“hotter drought”, an emerging characteristic of the Anthropocene—are the focus of rapidly expanding literature. Despite recent observational, experimental, and modeling studies suggesting increased vulnerability of trees to hotter drought and associated pests and pathogens, substantial debate remains among research, management, and policy-making communities regarding future tree mortality risks. In this invited “ESA Centennial Article” published in the August 2015 issue of *Ecosphere*, we provide

a synthetic roadmap to these debates. We start by summarizing key mortality-relevant research findings (>400 cited references altogether), differentiating between those implying lesser versus greater levels of vulnerability. Evidence suggesting lesser vulnerability (Table 1 in Allen et al. 2015) includes forest benefits of elevated [CO₂] and increased water-use efficiency; observed and modeled increases in forest growth and canopy greening; widespread increases in woody-plant biomass, density, and extent; compensatory physiological, morphological, and genetic mechanisms; dampening ecological feedbacks; and potential mitigation by forest management. In contrast (Table 2 in Allen et al. 2015), recent studies document more rapid mortality under hotter drought due to negative tree physiological responses and accelerated biotic attacks; rising background tree mortality rates and recent episodes of drought-induced forest die-off in all major forest biomes (Figs. 1, 2, 3); projected increases in drought

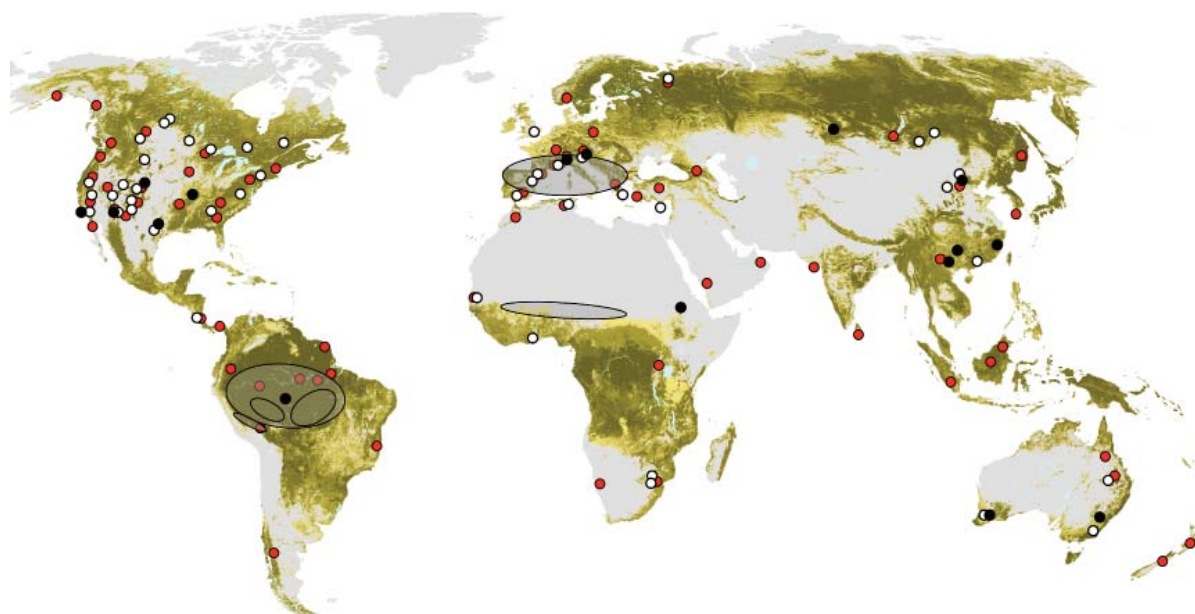


Figure 1. Locations of substantial drought- and heat-induced tree mortality around the globe since 1970, documented by peer-reviewed studies. Global forest cover (dark green) and other wooded regions (light green). Studies compiled through 2009 (red dots) are summarized and listed in Allen et al. 2010. Additional localities, documented by mostly post-2009 studies, include: the white dots and oval shapes derived from Figure 4-7 and its associated caption in IPCC (2014); and the black dots reported from other recent publications, listed in Fig. 2 in Allen et al. 2015.

frequency, intensity, and duration; limitations of vegetation models such as inadequately-represented mortality processes; warming feedbacks from die-off; and wildfire synergies.

Grouping these diverse findings we identify ten contrasting perspectives that shape the forest vulnerability debate but have not been discussed collectively (Table 3 in Allen et al. 2015). We present each of the ten contrasting perspectives by iterating through evidence associated with each—first for those findings implying lesser vulnerability, and then for those implying greater vulnerability. While we recognize that a gradient of perspectives exists, framing these perspectives as dichotomies (below) illuminates core issues of the forest vulnerability debate.

1. **Observations:** “Are the impacts of hotter drought on tree mortality and growth observed to date modest and spatially-limited?” OR “Are hotter droughts causing global increases in rates of background tree mortality and of broad-scale forest die-off events, along with increasingly substantial and widespread forest growth declines from many regions?”
2. **Temperature:** “Are the effects of warmer temperatures on tree stress and mortality relatively small?” OR “Do warmer temperatures greatly amplify tree stress and mortality?”
3. **CO₂ Fertilization & WUE:** “Will CO₂ fertilization and associated increased water-use efficiency (WUE) generally compensate for drought and heat stress?” OR “Are mortality processes associated with increasing drought and heat stress likely to overwhelm the compensatory effects of CO₂ fertilization and any buffering associated with increased water-use efficiency?”
4. **Physiological Acclimation & Adaptation:** “Are physiological acclimation and adaptation capacities large?” OR “Are physiological adaptive capacities small relative to the projected large and rapid increase in hotter droughts?”
5. **Phenotypic Plasticity:** “Will phenotypic plasticity and tree morphological adjustments strongly buffer drought and heat stress at both individual tree and forest levels?” OR “Are morphological adjustments too small to compensate for increased drought and heat extremes, and too slow to adapt to rapid fluctuations in growth conditions?”
6. **Genetic Variation & Selection:** “Will genetic variability and selection buffer drought and heat impacts at stand and population levels?” OR “Does within-species genetic variability provide only limited survival opportunities relative to the magnitude and rate of projected increases in drought and heat extremes?”
7. **Biological & Landscape Diversity:** “Will biodiversity and landscape heterogeneity buffer tree mortality impacts?” OR “Are the buffering effects of biodiversity and landscape heterogeneity insufficient to prevent increasing tree mortality impacts from hotter droughts, given the fundamental thresholds of physiological stress and mortality that exist for all species?”
8. **Future dynamics:** “Will future forest dynamics resemble the recent historical range of variability, with robust forest recovery after mortality episodes?” OR “Will forests respond to increasingly novel and extreme drought and heat conditions with greater tree mortality and novel ecosystems?”
9. **Models:** “Are current global vegetation models—which generally project greater increases in growth than mortality—accurate?” OR “Are current broad-scale vegetation models over-optimistic because CO₂ fertilization and temperature benefits to growth are included in the models but realistic mortality processes are insufficiently represented?”
10. **Management:** “Can management effectively mitigate the impacts of hotter drought relative to excessive tree mortality?” OR “Are management actions too limited spatially, and in intensity, to prevent widespread tree mortality impacts of hotter droughts on historical native forests?”



Figure 2. Dying *Pinus ponderosa* and *Pinus lambertiana* near Giant Forest in Sequoia National Park, southern Sierra Nevada, California, after four years of hotter drought, October 15, 2015. Photo: Craig Allen.



Figure 3. Mortality from hotter drought in Jarrah forest (*Eucalyptus marginata*) in the Darling Range of southwestern Australia, after canopy collapse at the end of Austral summer in March 2011, associated with a late February 2011 extreme heat wave after the driest year and second warmest year on record in 2010 (see Matusick et al. 2013), March 5, 2012. Photo: Craig Allen.

We also present a set of six global forest vulnerability drivers that are known with high confidence: 1) droughts eventually occur everywhere due to inherent climate variability; 2) climate warming produces hotter droughts; 3) atmospheric moisture demand increases nonlinearly with temperature during drought, increasing forest drought stress; 4) mortality can occur faster in hotter drought, consistent with fundamental physiology; 5) shorter droughts occur more frequently than longer droughts and can become lethal under warming, increasing the frequency of lethal drought nonlinearly (Fig. 4); and 6) mortality happens rapidly relative to growth intervals needed for forest recovery. These high-confidence drivers, in concert with research indicating greater vulnerability perspectives, support an overall viewpoint of greater forest vulnerability globally under projected climate warming (Fig. 5).

We highlight several general issues that may contribute to underestimation of forest vulnerability. First, interpretation of studies that focus on longer-term climatic trends, such as experimental manipulations of background warming alone, need to be differentiated from those that include extreme drought and heat events. Similarly, studies focused on drought but which do not include a mortality response need to be differentiated from those that do include tree mortality. Also, challenges in predicting threshold-type responses of tree mortality and forest die-off to hotter drought may enable a discounting of their probability. The limited range of our observations of past forest-climate conditions and interactions can constrain our ability to recognize, appreciate, and anticipate historically-unseen threshold responses and projected novel conditions. Additionally, the co-occurrence of multiple stresses, inadequately understood tipping-points, and the interactions of disturbance processes across spatial scales increases the difficulty of assessing cumulative risks of tree mortality from expected hotter drought.

Disconcertingly, the trends and magnitudes of changes in global forest health and tree mortality remain largely unquantified due to the absence of an adequate monitoring system, and global-scale models remain unable to accurately project the fate of the Earth's forests in response to hotter drought with confidence, despite the potential global consequences of high vulnerability to tree mortality. Finally, given the profound ecological and societal implications of underestimating global forest vulnerability to hotter drought, we also highlight urgent challenges for diverse research, management, and policy-making communities (Table 4 in Allen et al. 2015).

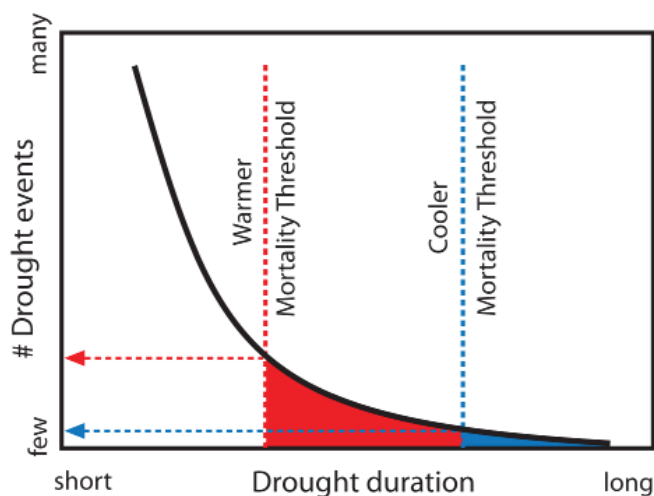


Figure 4. Drought frequency (black line) increases nonlinearly as drought duration decreases, as there are many more short-duration droughts than long ones (Lauenroth and Bradford 2009). With warmer drought (red dashed vertical line, warmer mortality duration threshold) trees die faster than with cooler drought (blue dashed vertical line, cooler mortality duration threshold), resulting in more tree-killing drought events at the minimum duration mortality threshold for hotter drought (red arrow line) than for cooler drought (blue arrow line). This cumulatively translates into more total tree-killing droughts under hotter drought conditions (filled red + blue areas) than under cooler drought conditions (filled blue area only) because many additional shorter duration droughts become lethal with warming (Adams et al. 2009).

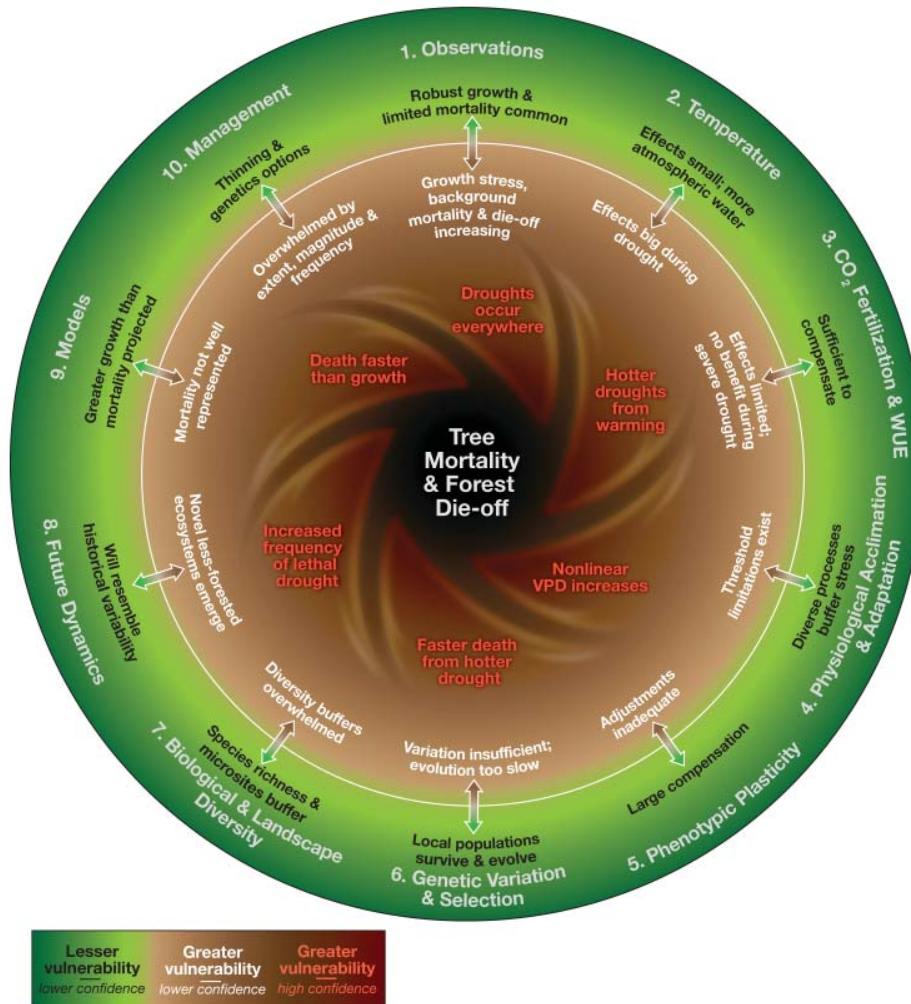


Figure 5. A synthesis of considerations regarding global vulnerability to tree mortality and forest die-off from hotter drought, highlighting the critical role of high-confidence drivers. Circular visualization of ten contrasting perspectives on the vulnerability of forests to hotter drought, presented clockwise sequentially around the outside zones; black text for lesser vulnerability perspectives and white text for greater vulnerability perspectives, arrayed on opposite sides of the neutral position of the circular white line. Arrows point outward from neutral toward lesser vulnerability (green background) and inward toward greater vulnerability (brown background). Around the center are six global drivers of tree mortality (inner red text) known with high confidence (i.e., little or no uncertainty), further increasing the vulnerability toward a central zone of tree mortality and forest die-off. WUE is “water-use efficiency”; VPD is “vapor pressure deficit”. Note that there is lower confidence in the overall vulnerability implications of the ten contrasting perspectives, both individually and collectively, relative to the set of six global drivers with high confidence that point to high vulnerability. We find that these high-confidence drivers, considered in concert with the cumulative weight of research pointing toward greater vulnerability perspectives, support an overall viewpoint of greater forest vulnerability globally than commonly reflected in recent studies and projections.

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Placing the 2012–2015 California-Nevada Drought into a Paleoclimatic Context

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“It behooves the prudent society to plan for its future by examining its past.” (Stine, 1998).

The ongoing 4-year western United States drought has created myriad challenges for water and natural resource managers to cope with and many landscapes are undergoing various drought-induced ecological issues. In an effort to estimate the severity of the current drought from a multi-century perspective, the current drought was evaluated with respect to the extreme and persistent droughts of the Medieval Climate Anomaly (MCA; ca. 850-1300 A.D.; Stine 1994) in the terminal Walker Lake basin of western Nevada and eastern California. Paleoproxy evidence supporting the MCA droughts from this region include reconstructed shoreline elevations from Adams (2007) and 14-C dated remains of submerged terrestrial plants in the West Walker River, Walker Lake, Mono Lake, Tenaya Lake, and Owens Lake (Stine 1994, Stine 1998). These drought episodes lasted between 140-240 years but occurred during a time when anthropogenic climate perturbations (such as radiative forcing and land use and land cover) were far smaller than today. The MCA droughts are benchmarks of abrupt and severe climatic change occurring within the range of natural variability, and we believe they can be used as worst-case scenarios for water resource management. This work also provided a basic evaluation of some watershed and lake system responses to abrupt climate transitions that are persistent in time.

Using a monthly, calibrated, semi-distributed watershed and lake model of the Walker Lake basin with dated shoreline elevations as modeling targets for steady state simulations, we estimated climate conditions for the MCA and current drought episodes. The average climate of the 2012-2015 drought was used to estimate steady-state lake levels under conditions of precipitation changes only and both precipitation and temperature for comparison with the lowstands estimated during MCA time. Because the two extended drought periods were bridged by a

relatively wet 50-year period (Adams 2007, Stine 1998), we also tested the feasibility of how wet this medieval pluvial period might have been while being able to satisfy the requirements of the second drought episode (regression to low lake levels; Fig. 1a). Examples of watershed responses (hydrographs of the West Walker River) to the varying climate conditions are shown in Fig. 1b. Lastly, the response of the lake to interannual variability was tested to ensure that several dry or wet years could not produce large fluctuations in lake level (Fig. 1c). The findings from these experiments yielded the following conclusions:

- 1) The precipitation reductions of the current drought, compared to the 1971-2000 period, are of a similar magnitude to the MCA droughts (~60%); 2) when current temperature anomalies are included, the current drought is more severe than the average severity of the MCA droughts; 3) the lake responds much more quickly to increases in precipitation than to decreases, suggesting the requirement of persistence to lower the lake from high levels to low levels; 4) as expected, warmer temperatures produce earlier peak melting and reduced flows during the falling limb of the hydrography, with 30-40% precipitation reductions yielding streamflow reductions on the order of 50% or more, consistent with the nonlinear relationship of precipitation to runoff in the watershed; and 5) the lake is not sensitive to interannual variability and acts as a low pass climatic filter. Ongoing work is examining how frequently, and of what magnitude, occasional ‘normal’ or wet years can occur and meet the imposed constraints of duration and required lake elevation regression.

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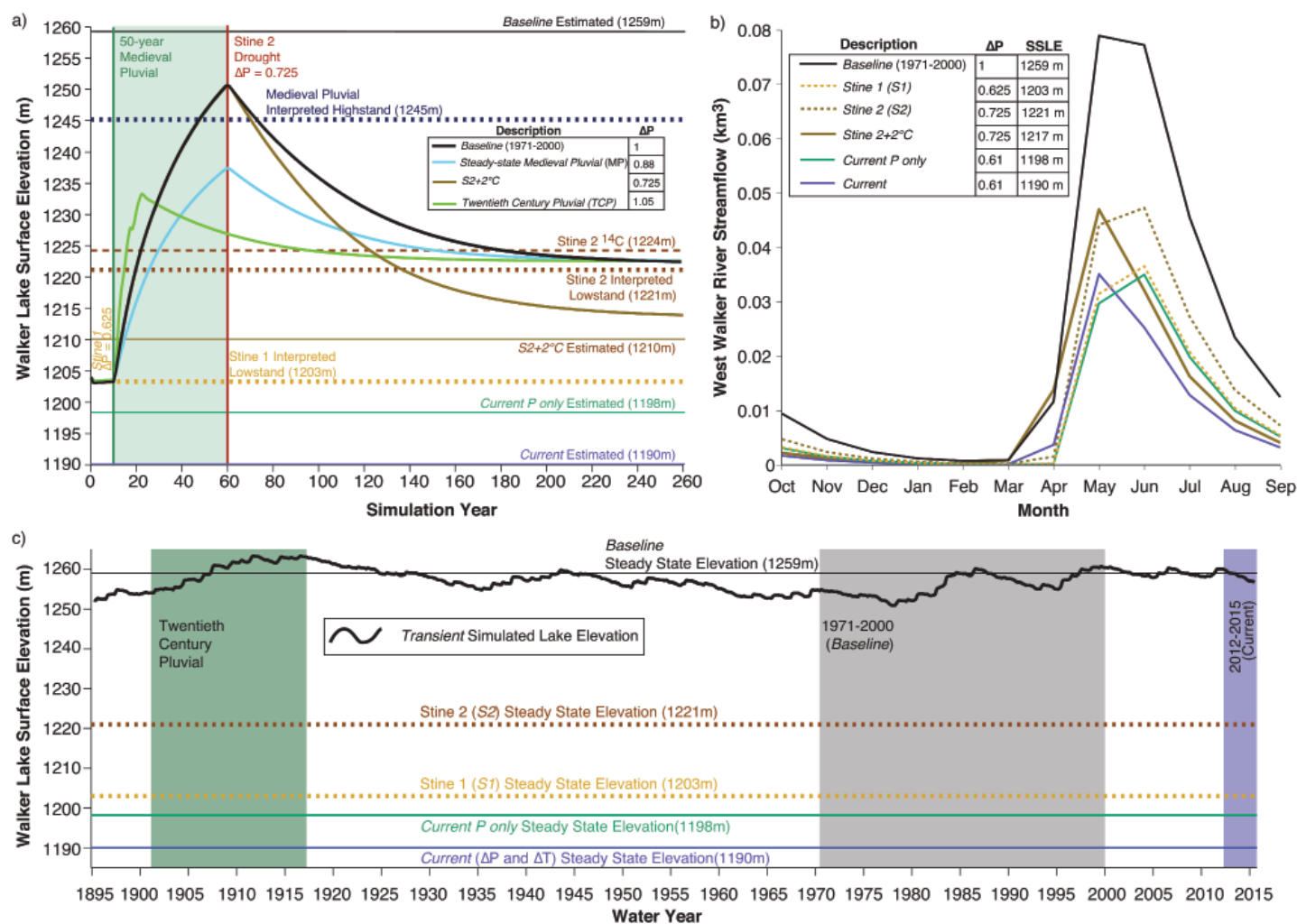


Figure 1: (a) Model simulations of Walker Lake surface elevation. To spin up the model, the lake was started at the more severe drought climate and elevation before a 50-year wet episode was applied (medieval pluvial) followed by a return to a drought climate for 200 years. Dashed green and purple lines indicate the steady state lake elevations for the current drought considering only precipitation (green dashed line; within 5 m of the more severe MCA lowstand estimated by Adams (2007)) and including both observed precipitation and temperature anomalies (purple dashed line; 13 m below the more severe MCA lowstand as atmospheric demands for water increase with temperature). (b) Monthly streamflow at the West Walker River under varying climates. (c) Full transient simulation of the period spanning 1896-2015 using PRISM (Daly et al. 1994) estimates of precipitation and temperature. Note that despite interannual variability, the lake oscillates about a mean elevation of 1255 m, which coincidentally is near the upper limit of Holocene lake levels. This implies that the last 100 years are wet by Holocene standards and agrees with the results shown in (a); the lake requires many (>10) years of persistent wet or dry climate in order to undergo large oscillations in elevation. Figure from Hatchett et al. (2015).



Cascading ice of Winthrop Glacier, Mount Rainier, Washington. Photo: Hassan Basagic.



Pedestal rocks on the surface of Palisade Glacier, Sierra Nevada, California. Photo: Hassan Basagic.

Investigations of Cirque Glaciation, Sierra Nevada, California

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Abstract

The Sierra Nevada of California has experienced two readvances of cirque glaciers since the demise of ice related to the Tioga Glaciation (equivalent to oxygen isotope stage-2 glacial maximum): the Recess Peak and the Matthes advances. Although these late-glacial and Holocene deposits (respectively) have been studied for more than a century, only in the last few decades have geologists obtained numerical constraints on their timing, extent, and paleoclimatic significance. These numerical constraints are based primarily on radiocarbon dating of sediment sequences in proximal glacial tarns, but a new effort is underway to provide fresh constraints on the spatial distribution and temporal coherence of moraine formation during the Holocene.

Moraines related to the Recess Peak advance occur below cirques throughout the Sierra Nevada, from north of Lake Tahoe to south of Mt. Whitney. The moraines are typically small volume with discrete crests and lie within several hundred to several thousand meters below the cirque headwalls but are well upstream of the nearest Tioga deposits. Although initially defined by Birman (1964) as a Neoglacial (late Holocene) advance, the Recess Peak event has subsequently been shown to be late-glacial in origin, following shortly on the heels of Tioga deglaciation (e.g., Clark and Gillespie 1998, Bowerman and Clark 2011). After the demise of the Recess Peak glaciers, the Sierra Nevada appears to have remained largely ice free through the rest of late-glacial and most of the Holocene. In the late Holocene, around or before ~3200 14C yr B.P. (3400 cal yr B.P.), cirque glaciers began to reform in the Sierra Nevada, but only reached their Holocene maximum during the Matthes (Little Ice Age) advance in the last ~700 yrs, perhaps as little as 150-200 yr ago. However, the timing and regional pattern of Holocene glaciation remains constrained only in a few valleys; a new effort is underway to develop comprehensive dating of Matthes moraines throughout the Sierra Nevada.

Introduction

The Sierra Nevada of California has a long and eventful history of glacial investigation, with many fundamental concepts of such studies originating there (e.g., Matthes 1930, Blackwelder

1931, Sharp 1969, Burke and Birkeland 1983, Nishiizumi et al. 1989). Most of these studies have concentrated on the Pleistocene glacial maximum moraines, including deposits related to the most recent maximum, the Tioga glaciation, which culminated about 20,000 yrs ago (e.g., Bursik and Gillespie 1993, Phillips et al. 1993). In contrast, relatively little work has been conducted on deposits related to the post-Tioga deposits, particularly those related to Holocene advances. As modern glaciers of the Sierra Nevada continue to shrink in the face of historic climate change, there is new incentive to study their history before they disappear entirely.

Early Work

The nature and timing of recent glaciation in the Sierra Nevada has been pondered since John Muir (1873) and Josiah Whitney (1882) tangled horns about whether active glaciers still existed in the range. Although Muir's stance favoring their presence was ultimately proved correct, there is much less certainty about the flip side of that debate: when did these modern glaciers first appear in the Sierra Nevada, and what were the spatial patterns and temporal pacing of their development since then? Given the historic shrinkage of Sierran glaciers, understanding their past development ironically may shed new light on future ecological changes in the region as the Sierra Nevada appears poised to return to a glacier-free condition.

The first geologists working in the Sierra Nevada generally considered the modern glaciers to be "feeble remnants" of the large Pleistocene glaciers (LeConte 1872), implying continuous occupation of the highest cirques through the Holocene. However, more recent work has indicated that the modern glaciers are in fact not left-overs from the Pleistocene but were instead reborn in the highest cirques sometime in the latter half of the Holocene. Matthes (1939, 1940, 1941, 1942, 1948) in particular was the first geologist to discuss in any detail the small glacial deposits that occupy many of the high cirques in the range, immediately downslope of active glaciers and snowfields (Fig. 1). He felt that the active glaciers and their adjacent moraines had formed only in the latter half of the Holocene, after

4000 yr B.P. To describe this period of recent glacier formation and advance, Matthes (1939) coined the term “Little Ice Age,” although that term is now generally used to refer only to the most recent late-Holocene cool period (last ~700 yr; Grove 2001).

Although his reasoning for defining this period was flawed (it was based on the time he presumed it would take for Owens Lake, on the east side of the Sierra Nevada, to reach its historic salinity level), the date itself as an estimate for onset of Neoglaciation in the Sierra Nevada serendipitously appears to be remarkably close to current constraints.

Following Matthes’ initial work, cirque deposits were largely ignored until Birman’s (1964) seminal research in Rock Creek and the Mono Pass area, where he defined two regional Neoglacial deposits: the earlier Recess Peak and the later Matthes moraines. Recess Peak and the Matthes deposits are spatially, temporally, and geomorphically distinct from each other, and from the Tioga deposits downstream. Close age control on both has been sparse until fairly recently, and most early studies relied

on either relative weathering parameters (e.g., Birman 1964, Yount et al. 1979, 1982) or on lichenometry (e.g., Curry 1969, Scuderi 1984, 1987) to date the deposits. Unfortunately, neither method appears to be particularly effective in the Sierra Nevada for establishing numeric ages for high alpine deposits between 1000 and 10,000 years old. The lichenometry in particular has provided misleading results. Curry (1969) established the lichen growth curve that has often been used in the Sierra Nevada. However, many control points for Curry’s growth curve come from lichens on unidentified and undated moraines for which he assumed a given age. Thus his growth curve for the prehistoric period (>100 yr B.P.) is generally poorly constrained, and involves circular reasoning when used to assign ages to cirque moraines.

Wood (1977) first established numerical ages of Matthes moraines when he identified a distinct Mono Craters tephra that covered all moraines in the nearby Sierra except the Matthes moraines. The relationship requires that the Matthes moraines



Figure 1. Oblique aerial view of northeast side of Mt. Brewer, southern Sierra Nevada, showing typical relationship of the two major cirque deposits in the range: Matthes (Little Ice Age) moraine under cirque headwall (A), and Recess Peak moraine below it in center foreground (B). A small, shaded, stagnant modern remnant of the Matthes-age glacier occupies the highest part of the cirque. Photo: Malcolm Clark, Sept. 23, 1977.

formed after deposition of the tephra. The tephra, originally radiocarbon-dated to 720 ± 60 ^{14}C yr B.P. (Wood 1977), was subsequently refined to 605 ± 20 ^{14}C yr B.P. (~ 600 cal yr B.P.; Stine 1990). Yount et al. (1982) found a similar tephra dated at 700 ± 60 ^{14}C yr B.P. on all but the Matthes moraines in the type area of the Matthes deposits. Together, these data demonstrate that the maximum extent of the Matthes advance occurred after ~ 600 cal yr. B.P.

At roughly the same time, Yount et al. (1979, 1982) documented the first evidence that at least some Recess Peak deposits in the type area predated the middle Holocene and were probably latest Pleistocene instead. By combining radiocarbon ages from soil pits inside Recess Peak moraines, and relative weathering data on moraines, Yount et al. (1982) concluded that some of Birman's Recess Peak deposits in Mono Creek were probably pre-Holocene. Their finding was recently confirmed and refined by Clark and Gillespie (1997), who retrieved sediment cores from lakes dammed by Recess Peak moraines in several places in the Sierra Nevada. Radiocarbon dates on basal sediments from these cores demonstrated that Recess Peak moraines were formed before $11,190 \pm 70$ ^{14}C yr B.P. (or $\sim 13,100$ cal. yr. B.P.). A radiocarbon date from the base of glacial outwash preserved in a lake downstream of a Recess Peak moraine provides a maximum limiting age for the Recess Peak advance of $12,200$ ^{14}C yr B.P. ($\sim 14,200$ cal yr B.P.; Clark 1997). Thus, the Recess Peak event is clearly a brief late-glacial readvance that appears to predate the European Younger Dryas cooling event. Furthermore, organic sedimentation in these lakes after the Recess Peak event suggests that glaciers were small or non-existent during the Younger Dryas period, in contrast to small glacier advances that apparently occurred in the Canadian and American Rocky Mountains during that time (e.g., Reasoner et al. 1994, Gosse et al. 1994).

The consistent absence of moraines between those of Recess Peak and Matthes advances in the Sierra Nevada indicates that the Matthes moraines represent the maximum advance of the Holocene. However, correlation of the Matthes moraines through the Sierra Nevada has relied strictly on geomorphic and relative weathering criteria; there has been few if any direct dates of the moraines, and until recently little was known about the timing of the initial growth of Matthes glaciers.

The first studies to put solid dates on the return of glaciers to the High Sierra indicated that glaciers there likely began to form roughly 3500 years ago, remarkably close to Matthes' (1939) original estimate (Konrad and Clark 1998, Bowerman and Clark 2011). These latter studies were based on analyses of glacial rock flour in lake sediments downstream of active glaciers. A significant limitation of these studies, however, is that they only

record the activity at two sites, the Conness and Palisade glaciers, leaving open the question of whether other cirques in the range have acted in tandem with these two glaciers, or whether there are more complex spatial and temporal patterns to Holocene glaciation in the Sierra Nevada.

In an effort to address this substantial gap in our understanding, I have joined a collaborative effort to constrain the timing and magnitude of Holocene glaciation in the Sierra Nevada across a broad latitudinal swath of the Sierra Nevada, from the Palisades in the south to the Crystal Range in the north (e.g., Fig. 2). The effort combines geologists from Lawrence Livermore National Laboratory (Susan Zimmerman, Alan Hidy, Robert Finkel, Center for Accelerator Mass Spectrometry), Yosemite National Park (Greg Stock), Lamont-Doherty Earth Observatory of Columbia University (Joerg Schaefer), and Western Washington University (myself and Will Cary, graduate student). The focus of the project is to date a spatially distributed suite of Neoglacial moraines using high-precision ^{10}Be cosmogenic exposure ages in order to test the timing and spatial coherence of Holocene glaciation in the range. In a parallel effort, we will be collecting lake cores from several lakes below the moraines in the Crystal Range and in Yosemite National Park to compare the glacial rock flour records from the glaciers to the dates on the moraines. Whereas the moraine dates should give us constraints on the timing of the maximum advance of glacier ice, the lake cores provide a continuous and independently dated record of glacier activity in the cirques.

Together, these records should provide the most detailed regional record of Neoglaciation yet developed for the western U.S. generally, and for the Sierra Nevada in particular. Because of the regional span of the study, this information will allow us to test hypotheses regarding the drivers of Neoglaciation (solar fluctuations, volcanic aerosol forcing, ocean circulation changes) as well as assess the response of the glaciers to prehistoric periods of cooling (e.g., Cook et al. 2007) and severe droughts (e.g., Stine 1994).

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Figure 2. Oblique view south of Matthes moraines of the Lyell and Maclure glaciers, Yosemite National Park and boulders on each moraine sampled for ^{10}Be cosmogenic exposure dating. Image date: 9/14/2013, Google Earth.

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Vanishing Ice, Vanishing History

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I pause to catch my breath at 11,000 feet. The sun glares off polished granite. Near the top of a small dome I locate a subtle ring of rocks, stand directly over it, pull out my camera, and zoom back in time.

In the summer of 1883, geologist Israel Cook Russell stood in this exact spot and photographed a panorama view of the Lyell Glacier (Fig. 1), the largest glacier in Yosemite National Park and second-largest in the Sierra Nevada. At that time the Lyell Glacier sprawled across two alpine cirques, covering more than a square kilometer. Now I hold his photo in front of me to compare: the lighting is similar, the perspective identical, but the glacier has changed dramatically. The Lyell Glacier now consists of only a few discontinuous patches of ice clinging to the shady cliffs. The overall surface area has shrunk by nearly 80% since 1883,

and the volume more than that. Although the Lyell Glacier, and the neighboring Maclure Glacier, retreated relatively steadily throughout the 20th century (Basagic and Fountain, 2011), the recent drought has taken a heavy toll; roughly 10% of the total area loss has occurred in just the past four years. These glaciers form the headwaters of the Tuolumne River, and their loss could threaten aquatic and riparian ecosystems downstream that rely on their late summer meltwater.

Of course, these changes are hardly surprising given the overwhelming glacier retreat that is occurring worldwide, and in that context the impending loss of these little glaciers may seem insignificant. Yet, along with the physical and biological impacts associated with glacier loss, I'm beginning to understand that there will be cultural impacts as well. Yosemite's glaciers have

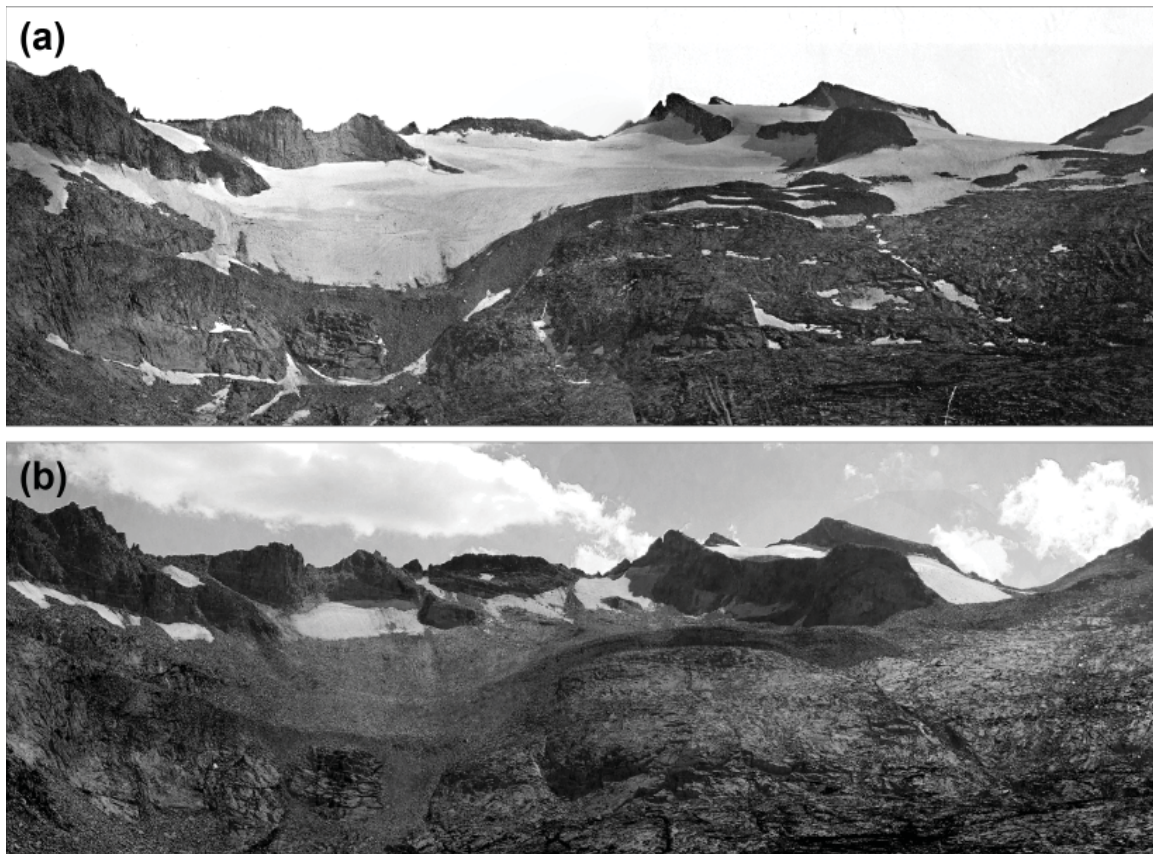


Figure 1. Repeat photographs of the Lyell Glacier taken in (a) 1883 by Israel C. Russell of the USGS and (b) 2013 by Jonathan Byers of the NPS.

an incredibly rich history of research, spanning nearly a century-and-a-half and including some of the most prominent geologists in the history of the West. As these glaciers vanish, so too do the physical ties to the glacier researchers who came before.

Of course, John Muir pioneered the effort. Muir began his Yosemite studies as a relatively unknown laborer, but he had the benefit of study under University of Wisconsin professor Ezra Carr, who in turn had learned from Louis Agassiz. Muir's keen observations led him to argue that Yosemite's iconic landscapes had a glacial origin, but his views met with resistance from more formally-educated geologists (Guyton, 1998). Muir no doubt hoped that his 1871 discovery of a "living glacier" in Yosemite's remote Clark Range would end the debate, but skepticism remained. Thus, in the summer of 1872, Muir, rankled by his critics, set out to identify true glacier movement: *"But notwithstanding the plainness and completeness of the proof [of glaciers in Yosemite], some of my friends who never take much trouble to investigate for themselves continued to regard my observations and deductions with distrust. I therefore determined to fix stakes in one of the more accessible of the glaciers, and measure their displacement with a view to making the ordinary demonstration of true glacial movement... The Maclure Glacier, situated on the north side of the mountain of that name, seemed best fitted for my purposes, and, with the assistance of my friend Galen Clark, I planted five stakes in it on the 21st of August, 1872, guarding against their being melted out by sinking them to a depth of five feet..."* (Muir, 1875).

Muir's methods were necessarily rather crude; he fashioned stakes from hand-hewn whitebark pine and surveyed them by "sighting across from bank to bank, past a plumb-line, made of a stone and black horse hair" (Muir, 1872). Nevertheless, these methods proved sufficient for his cause: *"On the 6th of October, or forty-six days after being planted, I found the [maximum] displacement... [to be] forty-seven inches in forty-six days, or about one inch per twenty-four hours"* (Muir, 1975). Joseph LeConte, the first professor of geology at the University of California, was persuaded by Muir's work and helped bring his ideas to the academic community (LeConte, 1873).

In 1883, I.C. Russell, the now-famous geomorphologist G.K. Gilbert, and topographer Willard D. Johnson visited the Lyell and Maclure glaciers as part of geological explorations of the Mono Basin commissioned by the U.S. Geological Survey (USGS). They were better equipped than Muir, and produced very detailed photographs and maps of the glaciers (Russell, 1885). Among their many valuable contributions was confirmation that the terminal moraines at the front of the glacier were forming in 1883. Gilbert returned in 1903 and 1908 to take additional

photos, noting little change to the glaciers during that interval.

In the early part of the twentieth century, the USGS charged geomorphologist Francois Matthes with the task of evaluating Muir's ideas of a glacial origin of Yosemite Valley. As part of his overall studies of glacial landforms in Yosemite, Matthes visited the Lyell and Maclure glaciers in 1936. Matthes understood the importance of glaciers as climate change indicators and water reservoirs, and he presciently argued for their long-term monitoring: *"Why is it important that we should measure our glaciers? What need is there of going to all of this trouble, and what purpose will be served by the results? The answer is that glaciers are extremely sensitive to climatic fluctuations and register them more vividly than do streams, springs, lakes, or vegetation; and since we have so delicately, so daringly adjusted some of our great agricultural and engineering enterprises and their dependent industries to existing climatic conditions, it behooves us for the good of our complex American civilization to keep a close watch on climatic changes or fluctuations, however slight and transient, that may be taking place"* (Matthes, 1935).

At Matthes' urging, the National Park Service (NPS) initiated annual monitoring of the Lyell and Maclure glaciers in 1931. NPS naturalists – often sporting full ranger uniforms (Fig. 2) – repeated photographs from Russell's and Gilbert's photo points, established new photo points, conducted a variety of surveys documenting glacier size, thickness, and velocity, and noted a host of unusual features, including a perfectly mummified bighorn sheep in 1933. During a 1936 survey NPS rangers discovered one of Muir's whitebark pine stakes. Among the notable survey participants was David Brower, who would go on to lead Muir's Sierra Club. The NPS monitored the glaciers near-annually until the 1960's, noting substantial reductions in their size and thickness (the NPS reports are available from the Glaciers of the American West webpage: <http://glaciers.us/Downloads>). The last survey of that era occurred in 1975.

There followed a bit of a "dry spell" for Yosemite glacier studies, with only sporadic photographs taken by hikers and glacier enthusiasts (the exception being a mass-balance study of the Maclure Glacier by the USGS; Tangborn et al., 1977). In the 1990's Yosemite resident naturalist Pete Devine visited the glaciers and, intrigued by the benchmarked photo points, spent years repeating photos as often as he could. Portland State University researchers Hassan Basagic and Andrew Fountain revived surveys and repeat photos of Sierra Nevada glaciers in the early 2000's, publishing a summary of their 20th-century retreat (Basagic and Fountain, 2011). In 2006, my first year as Yosemite Park Geologist, I joined Pete on a glacier survey trip and I haven't missed a year since. In 2009, in collaboration

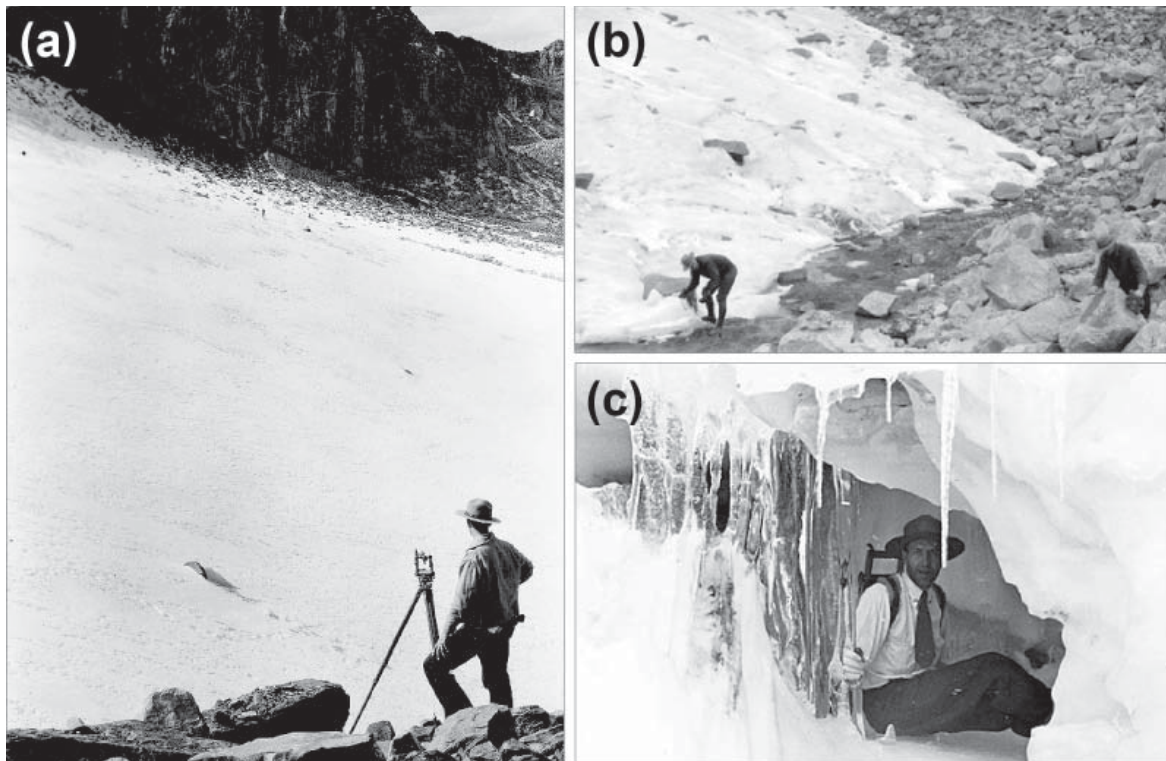


Figure 2. Photographs from National Park Service glacier surveys in the 1930's. (a) Surveying the ice surface elevation of the east lobe of the Lyell Glacier in 1934; this transect now runs entirely across bedrock. (b) Measuring the position of the front of the west lobe Lyell Glacier in 1932. (c) A National Park Service naturalist explores an ice cave in full ranger uniform in 1935.

with Robert Anderson of the University of Colorado, Boulder, and with funding from the Yosemite Conservancy, we began a detailed re-assessment of the glaciers, combining the traditional photography and surveys of the past with remote sensing data from planes and satellites.

Sometime in 2011 I realized that 2012 would mark 140 years since Muir had measured movement of the Maclure Glacier, and it occurred to me that we ought to repeat his measurements, using a similar stake configuration (admittedly on a much smaller glacier) and reproducing his measurements to the day. We placed our stakes on the afternoon of August 21, 2012. We opted not to use whitebark pine stakes or horse-hair plumlines, instead utilizing PVC stakes, laser rangefinders, and differential GPS (Fig. 3), but the essence of the measurements was the same. On the morning of October 6, I entered the last of the data into my notebook, did a few quick calculations, and sat back, stunned; over that time period the Maclure Glacier had moved – and I might as well just quote Muir here – “forty-seven inches in forty-six days, or one inch per day”. Despite being less than half the size it was in 1872, this “living glacier” was still moving at the same rate measured by Muir. I had already felt a strong bond with Muir just by repeating his measurements, but now we shared the

same result as well! The bond was sealed later that month when Pete and I “rediscovered” Muir’s whitebark pine stake in our park archives (Fig. 3) and I got to hold it in my hand. The marks from Muir’s axe were still visible.

The Lyell Glacier, however, was another story. Over the same August-to-October time period we detected no movement there, and measurements over multiple years confirmed this result. Sometime since the NPS had measured its velocity in the 1930's the Lyell Glacier stagnated, ceasing its downward motion. Given that movement is a defining feature of a glacier, perhaps the ice body on Mount Lyell deserves another name? Or maybe it's a moot point, as trends suggest that the ice may soon disappear entirely (Fig. 4). Last year marked a turning point, as bedrock appeared in the middle of the western lobe of the “glacier”. Not only does this new exposure hasten melting by absorbing more solar energy and increasing the melt perimeter, it also places firm constraints on the remaining thickness of ice, which is on the order of only 5-10 meters. During the past four years of drought the glacier has lost 1-2 m of ice thickness per year, suggesting that the remaining thickness may be gone within a decade or so. Standing on the granite dome with Russell’s 1883 photo in my hand, I can’t help but feel a sense of loss.



Figure 3. Repeating John Muir's measurement of glacier movement. (a) One of the whitebark pine stakes (broken in half) that Muir used to measure movement of the Maclure Glacier in 1872. The stake was collected by National Park Service naturalists in 1936 and placed in the Yosemite Museum, where it was "rediscovered" in 2012. (b) Repeating Muir's measurement on a much-reduced Maclure glacier in 2012, using more modern technology but essentially making the same measurement. Surprisingly, the rate of movement in 2012 was the same as that obtained by Muir 140 years earlier.

Observing such rapid change has forced me to reckon with the real possibility of a glacier-free Yosemite in my lifetime. From a scientific standpoint I can understand the physical aspects of glacier loss through data analysis, and that almost provides a sort of refuge, but lately I've been thinking a lot about the associated loss of human history. I learned that science is supposed to be an ongoing process of discovery that builds on the work of previous researchers, and through my glacier studies I've felt a strong connection to these researchers. I've shared the joy of crunching crampons into clear, hard ice, the thrill of exploring sub-glacial tunnels, and the frustration of losing stakes to rapid melting. Now, I worry that those strong connections, made tangible by the glaciers, will disappear along with the ice. Soon there will be no more work to build on. I'm humbled by the prospect of possibly being the last participant in this arc of history.

I feel extremely fortunate still to be able to experience this history first-hand, and I am determined to share that experience with as many people – especially young people – as I can. For now, we are still a part of the rich history of glacier research in Yosemite, but the end is in sight.

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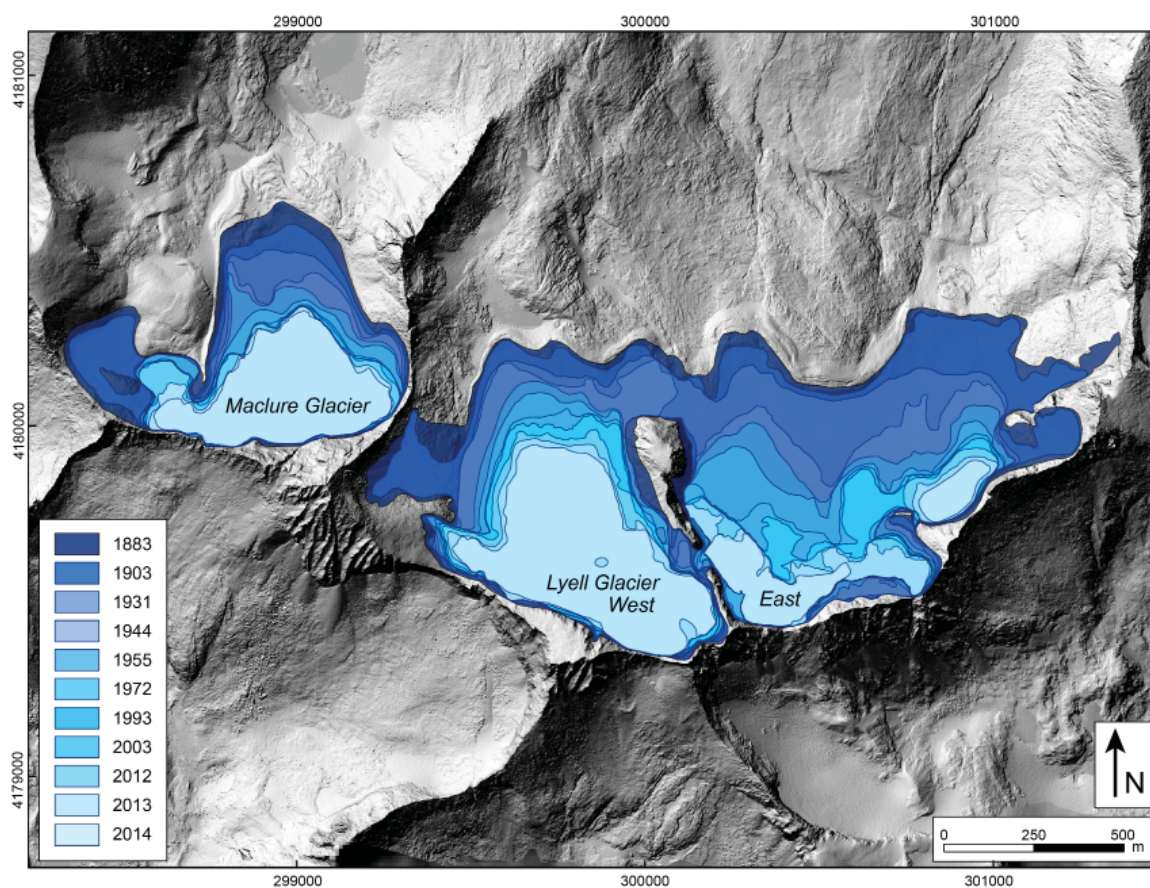


Figure 4. Surface area change of the Lyell and Maclure glaciers from 1883 to 2014; incorporating data from Basagic and Fountain (2011). Since first mapped in 1883 the glaciers have lost approximately 80% of their surface area; roughly 10% has occurred in just the past four years.



Greg follows his National Park Service predecessors by sporting his own full ranger uniform while exploring modern Yosemite ice caves. Photo: Keenan Takahashi.

Rock Glaciers of the American West

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Rock glaciers are landforms composed of a creeping mix of ice and rock debris that are common to many high alpine regions. Our broad interest in rock glaciers draws from their potential as paleoclimate indicators defined by their spatial distribution relative to alpine glaciers, as potential archives of paleoclimatic information, and for their contribution to alpine hydrology and ecology. Rock glaciers are unrecognized as a source of water in high alpine regions and may play an increasingly important role as the climates of these regions warm and dry in future decades (Fig 1).

We focus on the rock glaciers of the American West, exclusive of Alaska, where our preliminary survey shows that more than 10,000 rock glaciers may reside, at least four times the population of glaciers. A cursory review of air photos and published literature revealed that many regions with numerous rock glaciers are not recognized in the scientific literature. We are in the final stages of developing the first comprehensive inventory of rock glaciers in the West providing initial estimates of subsurface ice area and volume (Fig. 2). The magnitude of subsurface ice and

its wide distribution across the West may come as some surprise to many alpine scientists and motivate increased research in rock glaciers and its influences on alpine hydrology and ecology. Also, expanding human usage of alpine environments has increased construction on or near rock glaciers and identification of these features prior to construction is a valuable contribution to state and federal land-management agencies as well as the private sector.

Rock glaciers inhabit the same alpine environments as glaciers but are also far more widely distributed (Fig 3). Compared to glaciers, rock glaciers are found at higher elevations, slightly lower temperatures, and with much less precipitation, including snowfall.

Beyond the rock glacier inventory and climatology, we are examining how the influence of rock glaciers on stream water chemistry and microbiology, and on riparian vegetation differs from glaciers.



Figure 1. Google Earth image of a rock glacier in the Uinta Mountains, Utah. Width of the rock glacier at the arrows is about 300 m.

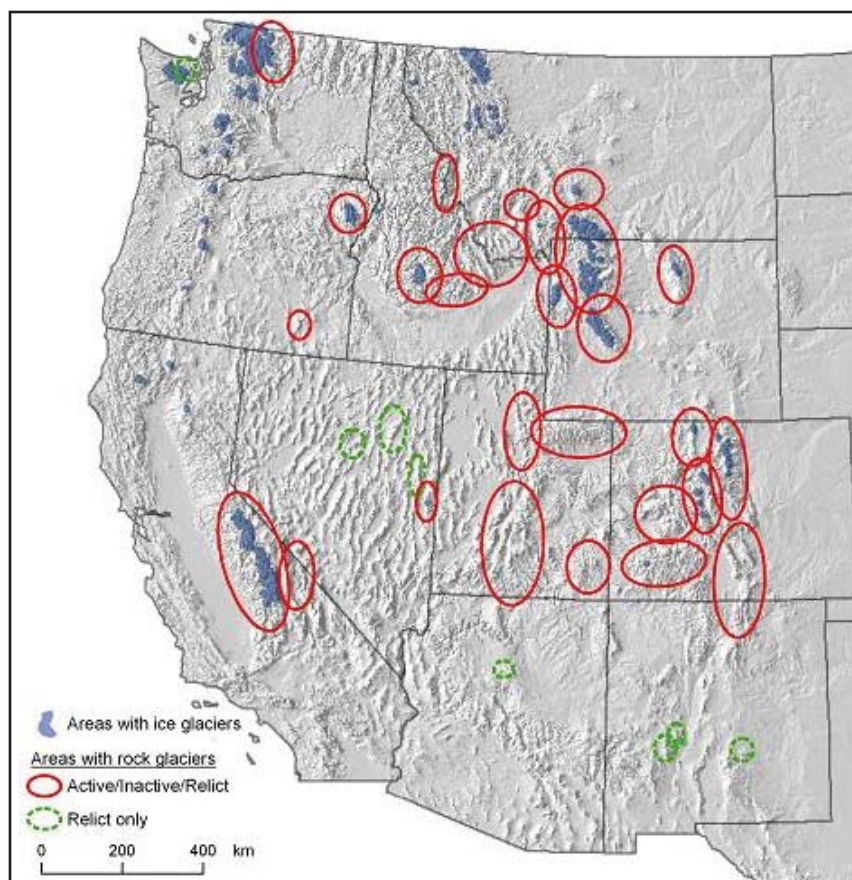


Figure 2. Generalized distribution of rock glaciers (preliminary) and ice glaciers in the American West.

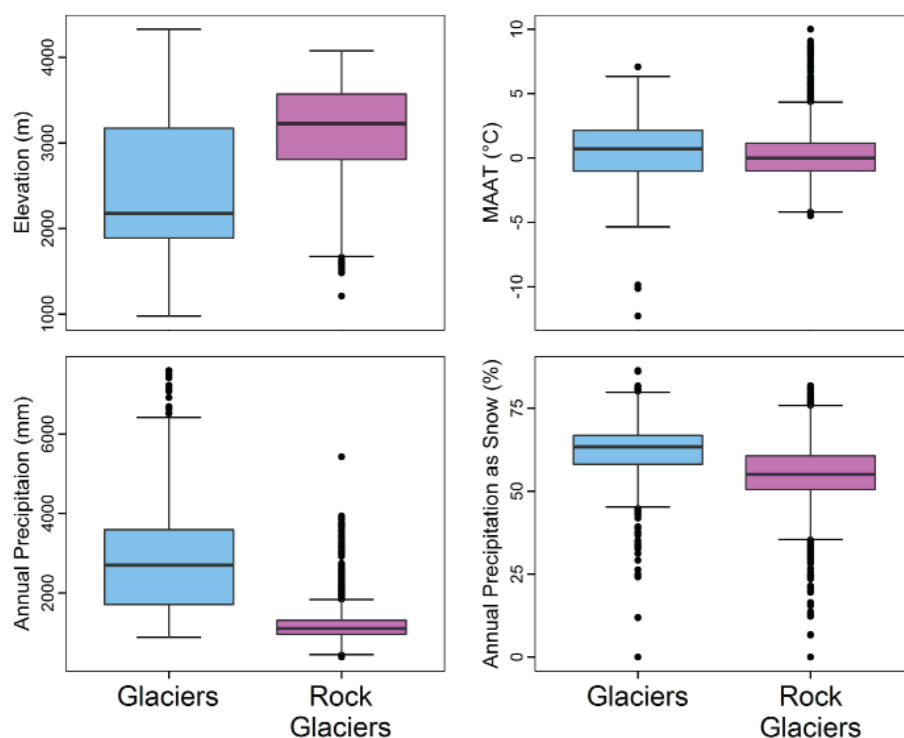


Figure 3. Elevation, annual air temperature, and annual precipitation at the glaciers and rock glaciers in the western US, exclusive of Alaska. G indicates glaciers and RG indicates rock glaciers. The temperature and precipitation data are from PRISM 1981-2919 normals. Snow is estimated as precipitation that falls during months where mean air temp is below zero.



Gibbs Rock Glacier in the Sierra Nevada, California, feeds Kidney Lake, and is a source of perennial water for downstream ecosystems.
Photo: Connie Millar.

Glacier Views through Time: An update from the Glacier RePhoto Project

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The Glacier RePhoto Project at Portland State University continues to document glacier change throughout the American West. We compiled the location of 210 historic rephoto “stations” from which glaciers were photographed. The rephoto station location and photographic information, including photographer, date, and source, are stored in a GIS database. Over the past several years, hundreds of new photographs were added as we

reoccupy the various stations. The photographic archive now totals 1140 photographs featuring 60 glaciers located in the Sierra Nevada, Trinity Alps, and Mount Shasta of California, Cascade Volcanoes in Oregon and Washington, the Olympic Mountains, Washington and the Front Range of Colorado. Included here are a few examples (Figs. 1-6).

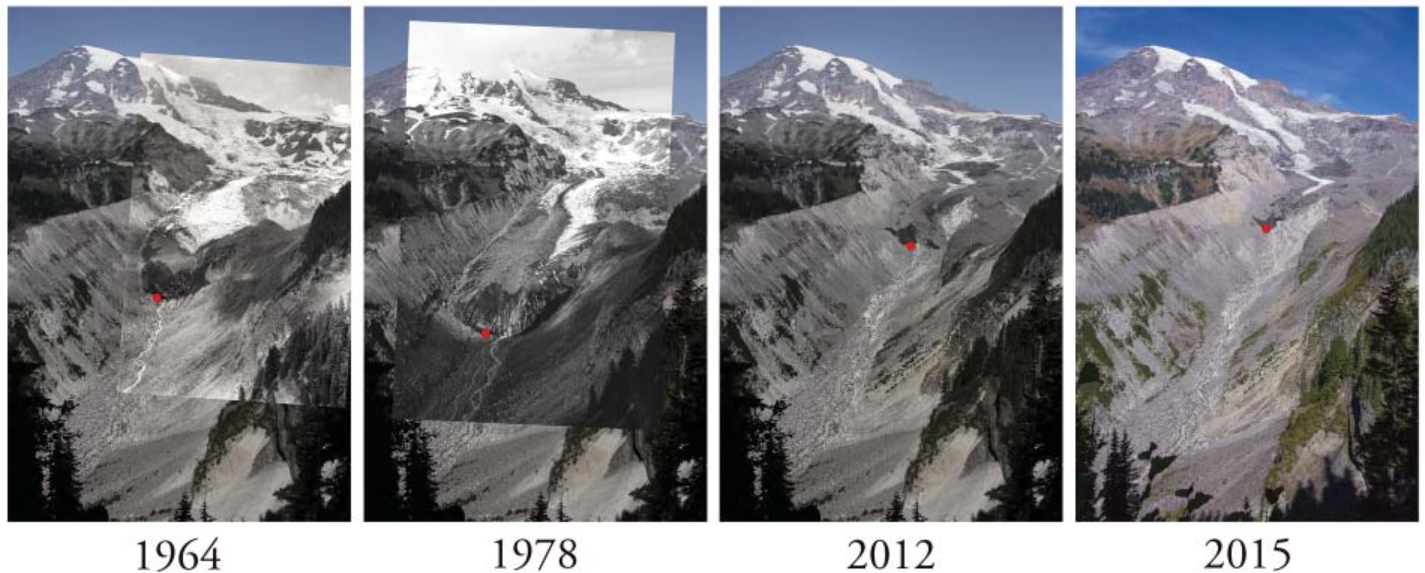


Figure 1. Nisqually Glacier, Mount Rainier. When Station 5 was first occupied in 1940 by F.M. Veatch of the National Park Service, the glacier filled the canyon. The glacier terminus retreated, advanced, and retreated, highlighted with red dots in the frames above. Significant retreat and a lowering occurred between 2012 and 2015. Note: The background image for the first two panels is the 2012 image on which the specified year image is superimposed. (1964: F.M. Veatch, National Snow and Ice Data Center; 1978: D.R. Crandell, U.S. Geological Survey).

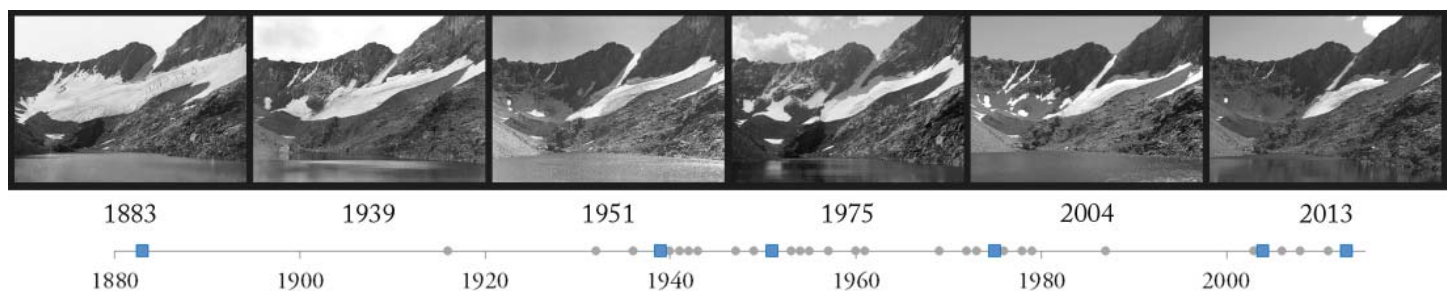


Figure 2. Dana Glacier, Sierra Nevada. An example of the wealth of rephotographs taken over the past 130 years at Photo Station 4, established by I.C. Russell in 1883. The scale at the bottom shows the distribution of the 32 photographs available (grey dots) and selected photographs (blue squares) shown above.



Figure 3. Klickitat Glacier, Mount Adams. Station 1055, established by Harry F. Reid in 1901. Glacier rephotography assists mapping historical glacier boundaries, particularly on volcanoes, where geologic evidence of past glacier extents is often lacking due to erosion. Matching perspectives allows the historical glacier extent (yellow dot) to be transferred to the modern landscape, which can be compared to the modern glacier terminus (red dot).



Figure 4. Conness Glacier, Sierra Nevada, Station 5555 established by W. Dumire in 1957 (National Park Service) just below the summit of North Peak.



Figure 5. Eliot Glacier, Mount Hood. Station 995, established by Harry F. Reid in 1901. The image on the left features the glacier terminus covered with rock debris. The glacier has retreated and vegetation has encroached in the 2014 frame. Many historical photo stations established at or below tree line have become overgrown.



Figure 6. Mazama Glacier, Mount Adams. Station 1017. A dramatic retreat over the 20th century leaves this photo station stranded in mid-air. Relocation of this station is therefore approximated on the ground.

Overview: *Mountains of our Future Earth* Conference

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The international conference *Mountains of Our Future Earth* took place in Perth, Scotland on 5-8 October 2016. It was organised by the Centre for Mountain Studies (CMS) at Perth College, University of the Highlands and Islands (UHI) and two global organisations – the Mountain Research Initiative (MRI) and the Global Mountain Biodiversity Assessment (GMB). A total of 400 scientists and practitioners from 51 countries participated, from a very wide range of natural and social science disciplines. They had the opportunity to present their research in 46 parallel sessions, 7 roundtables and a poster session, as well as to hear keynote presentations from 7 global experts. The title of the conference indicates its aim to contribute to the new global 'Future Earth' programme, a 10-year international research initiative that will develop the knowledge to respond effectively to the risks and opportunities of global environmental change and support transformation towards global sustainability. This was the topic of the final panel discussion at the conference,

bringing together scientists and research funders from around the world. The abstracts of all the presentations at the conference are available from the CMS (info.cms@perth.uhi.ac.uk). Keynote presentations can be found on the MRI website at <http://mri.scnatweb.ch/en/events/2015-01-29-07-56-51> as well as blogs about the parallel sessions at <https://perthmountains2015.wordpress.com/>.

A special issue of the quarterly journal *Mountain Research and Development* (www.mrd-journal-org) will be published in 2016, including an analysis of all the presentations and a number of papers presented at the conference. Other special issues of journals are also planned. For more information, please visit the conference website, www.perth.uhi.ac.uk/subject-areas/centre-for-mountain-studies/events/perth-iii-mountains-of-our-future-earth.



Isle Ornsay, Isle of Skye [Scotland]. © Amy Holden (Woolvin).

African Mountains and their Challenges

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With African mountain research being some of the least-well represented in the international mountain research arena, it was a privilege to chair a session dedicated to African mountains at Perth III. This session nevertheless presented only a fraction of the very important work being done in numerous disciplines in African mountains. It also highlighted the need for continental-scale research collaborations that can study patterns of change in African mountain in a manner comparable to other continents. The comments below are just some of the aspects being researched and documented on African mountains, profiled at Perth III.

Prof. Andreas Hemp (Bayreuth University, Germany) highlighted the factors driving rapid change on Mount Kilimanjaro. Although the loss of Kilimanjaro's ice-cap has been a flagship for showcasing global warming impacts in Africa, loss of the lower-altitude cloud forest through drying climate and more frequent fires is actually the most serious change being experienced. The icecap itself contributes a negligible amount of water to lowland beneficiaries compared to that of the cloud forest.

That 'elusive species' – sustainable development – was tackled by Dr. Sue Taylor (Co-ordinator of AfroMont, University of Pretoria, South Africa), who explored suitable indicator options for tracking sustainable development in African mountains. She used examples from some larger transboundary mountain conservation projects, and profiled the challenges of macro-governance issues and their impacts on sustainable mountain management.

Mountain tourism is a major income contributor to many African countries. Prof. Mari Oiry Varacca (Université de Savoie Laboratoire, EDYTEM, France) elucidated the impacts of social change in the mountain tourism landscape in northern and western Africa, and the impacts of the Arab Spring and other socially seismic events on local tourism potential and responses from the industry.

Many people outside of Africa are surprised to know that snow is common in several African highland areas. Mr. Timm Gross (University of Bern, Switzerland) showed that there is great inter-

annual variability – but no evidence at this point of any long-term changes – in snow cover patterns in Lesotho over a space of 14 years, using satellite imagery.

The emphasis of Perth III was on change in mountain environments, and Mr. Luke Bentley (Rhodes University, South Africa) guided us through the complexities of modelling the potential responses of montane plant species to climate change and the various future scenarios that could be played out. The potential responses include the expected inter alia altitude climbing, altitude shedding, contraction, and range shifting.

The final presentation (mine) explained the fundamental role of rigorous fieldwork in mega-biodiverse mountain regions. Such fieldwork is essential for supplying enough robust data on the distribution and ecology of local endemics to be able to predict responses (if only intuitively) of the endemic mountain biota to climate change. Much of Africa is still in the 'Age of Exploration' in which databases are unhelpful due to the lack of comprehensive biodiversity knowledge.

The session concluded with a synthesis on key aspects for future African mountain research:

1. Africa will – according to IPCC models – be largely negatively affected by climate change. There is a need for a collective African effort to study and monitor these impacts continentally in African mountains, with 'mega-modelling' results that can be compared to other continents.
2. There is a need for skills transfer/specialists from the North (and South-South) to collaborate with African researchers on these topics, to bring African mountain climate change research on par with Northern standards (bearing in mind the very often different ecological context in African mountains, such as fire being an essential natural driver of diversity in many mountains, and the concept of a treeline being ambiguous in some contexts).
3. As elsewhere in mountains around the world, there is a drastic need for improved fine-scale high elevation biodiversity and climate data. This will require extensive field hours and investment expense.

4. Options for a 'mega-repository' of African mountain data (all disciplines) can be explored. Such a facility would streamline African mountain research.
5. Governance issues are critical to the success of mountain research in Africa: unstable political environments, civil conflict, and other political/worldview issues hinder progressive research agendas and large-scale collaborations. There is an increasing trend towards international co-operation and integration on environmental topics in Africa (especially in the south and east).
6. There is a need for a unified 'African Face' to represent African mountain research to the rest of the world and to create a forum for international collaboration.

Anyone interested in African mountain research can connect with the African mountain research community via AfroMont (Contact Dr. Sue Taylor, staylor@zoology.up.ac.za).



Africa's mountains offer a pot of research gold in terms of biodiversity-exploration rewards and trans-disciplinary collaborative opportunities. Photo: Ralph Clark.

Sustainable Tourism Development

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We present key themes raised in presentations by researchers and practitioners on sustainable tourism development in mountain regions as part of the *Mountains of our Future Earth Conference*. The session was divided into two blocks on Wednesday 7 October 2015; one held in the morning, chaired by Gary Grant and the other in the afternoon, chaired by Carolina Adler. From these sessions, 3 themes emerged: 1) Co-design and co-production of knowledge 2) Robustness and 3) Assessment and evaluations.

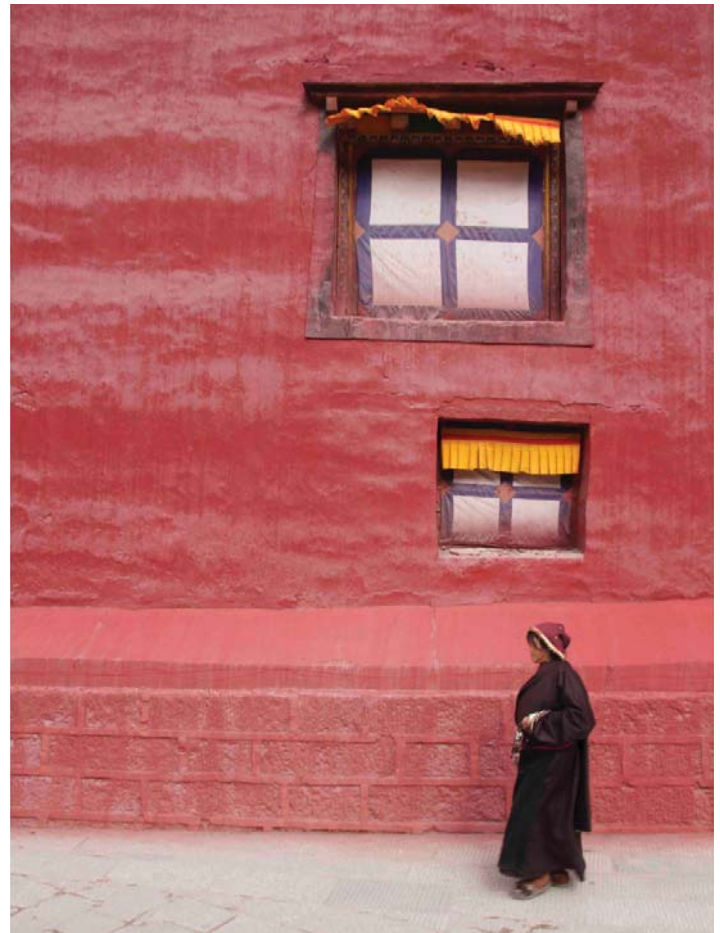
The first theme was recurrent in almost all presentations: there is an urgent need for researchers to better practice co-design and co-production of knowledge with multiple and diverse stakeholders to strategically plan, implement and assess sustainable tourism development initiatives. It is essential to identify and carefully distil the perceptions and values of stakeholders with regards to these initiatives; such measures are key to reducing the risk of community backlash or of developing projects that fail to appeal to, or have any relevance to, stakeholders. For example, a study by Mary Benjamin (University of Calgary) identified seven critical factors that influence the mountaineering experience for mountaineers. Benjamin explained how these factors inform



better management practices in mountaineering destinations and help to sustain visitation rates by developing a niche market tailored to visitor expectations. Gary Grant presented another example of a tourism destination development plan for a small part of the eastern Himalayas in the Tibetan Autonomous zone. The presentation emphasised sustainable tourism principles, community involvement, and adequate planning as key success factors that also minimize negative impacts upon the



environment, culture and local economy. A third case from France, presented by Pierre Derioz (University of Avignon) and Olivier Hoibian (University Paul Sabatier), depicted a process of transformation from the closure and demolition of a power plant to the development of a sports and recreation complex. Trade-offs between different meanings and consequences that the transformation had for each stakeholder group was a key issue. A number of challenges was also mentioned, including: the underutilisation of traditional sports infrastructure (e.g. tennis courts), given the small local population that could make use of these facilities, lack of accommodation for tourists and visitors, and the legacy of the power plant itself, perceived by some as “off-putting”. A final take on co-design and co-production of knowledge came from Valerie Thöni (UIAA), who presented the UIAA’s Mountain Protection Award (MPA), a project showcasing sustainable tourism development in mountain regions. Thöni highlighted the important role that mountaineers can play in the monitoring and reporting of processes of environmental and socio-economic change in mountains as a vital yet underutilised knowledge resource. The UIAA MPA was also portrayed as a means to identify relevant issues for local communities that could benefit from scientific collaboration, rather than focusing solely on researcher-led topics. This collaboration has the potential to drive transformative research that yields solutions in a transdisciplinary manner.



Robustness emerged as the second key theme highlighting the need to build and look at tourism as ‘systems’ that inter-link and network tourism enterprises and destinations, especially given the seasonal and often short-term planning horizons in tourism. A case study on a rural tourism initiative in north-eastern Portugal, presented by Silvia Nobre (Polytechnic Institute of Braganca) showed that whilst the number of local accommodation projects increased, the lack of networked tourism products and activities on offer meant a limited tourism potential in this region. Nadine Houbé (Austrian Academy of Sciences) showed how mapping farm holiday website hits in Austria can reveal patterns of not only internet use of prospective tourists, but also actual bookings. The utility of this tool rests on the use of open-source and openly available data such as Google Analytics to visually see a more systematic “map” on the demand side of tourism that can be used for strategic targeted marketing.

Finally, assessments and evaluation was raised as the third key theme, and one that we consider an important emerging topic for sustainable tourism development. For example, Qobiljon Shokirov (University of Zurich) presented a systematic review of the state of mountain tourism and sustainability research in Kyrgyzstan and Tajikistan. The review yielded many insights; for example, the current literature focuses mostly on economic growth and local prosperity, with very little (almost none!) attention given to environmental or cultural considerations. This focus on economic growth is important to note if we consider that sustainable tourism development should also account for cultural, social and environmental aspects.



Overall, a key take-home message from the entire session was the need to broaden out and include other perspectives and voices that include tourism professionals, practitioners and communities who have actual experience in implementing and assessing the value and merit of sustainable tourism initiatives. In other words, we need to find the means and structures to make sense of and legitimise phronesis, or ‘practical wisdom’. Experiences are key for learning about what works, for whom and how, as well as helping researchers to focus on salient issues that matter on the ground. Furthermore, these experiences depict conditions under which certain measures work in realising sustainable development objectives that are necessarily complex and context-specific. It is important to learn about these conditions as mechanisms or models to aggregate knowledge at scales that are relevant for decision-making. Focusing on the transferability, rather than the generalizability, of these mechanisms as a means for scaling and aggregating knowledge is important. We believe that transferability is a topic that the research community should focus on if we are indeed concerned with making a measurable impact on the sustainability front.



All the images in this article are by Gary Grant, taken in western Sichuan, Tibetan autonomous region, and Dege.

Sacred Mountain Landscapes and Biocultural Diversity

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The session on Sacred Mountain Landscapes and Biocultural Diversity had only five papers, but the depth of analysis, the warmth of the discussion, and the enthusiasm of the participants were wonderful.

A number of recurring themes emerged across the five papers. The first was the sense that the 'sacred' is often used as an excuse for something else. In Robert Zomer's (Kunming Botanic Gardens) paper, the sacred was used as an 'entry point' to allow for transboundary negotiations where questions of water or actual international boundary demarcation were too sensitive. The use of the term 'sacred' in the Kailash Sacred Landscape—shared between India, Nepal, and China—thus allowed for a suspension of politics in a highly politicized negotiation. This sidestep made it possible to agree on path-breaking transboundary agreements in a fragile and threatened area.

In Karubaki Datta's (North Bengal University) paper, the sacred was woven into the political history of Sikkim, India. Over the last two centuries, sacred sites became sites of ethnic resistance as the power structures in the state changed. As she pointed out, where elsewhere in the world sacred groves were being lost to development and changing values, in Sikkim they were thriving (at least in the traditionally Bhutia and Lepcha areas) because they were connected with identity politics in a contested landscape.

A certain discomfort with this approach emerged in the questions—is the sacred only an entry point? Is it only an instrumental category? At the same time, these first two papers made it clear that the sacred is political. Fausto Sarmiento's (University of Georgia) paper—discussed below—returned to this question when he proposed a political ecology of the sacred.

There is a good reason for methodological slipperiness here. We agreed that analysing—let alone measuring—any relation between 'sacrality' and biodiversity is very difficult. Challenges include the problematic category of religion with its colonial and ethnocentric associations, the relationship between biological and cultural diversity, and the challenge of measuring phenomena that emerge from the interplay of mutually exclusive experiences.

As a transdisciplinary, collaborative, postcolonial project, ethnobiology may be the best mode of research to capture this relationship. There are ongoing projects involving a number of the panel participants that are trying to do just that.

The second sense that emerged was that defining, or at least analysing, the sacred is possible and necessary but there is no general theory of the sacred. Rather, every instance of a sacred site is an ongoing process in a local environment, negotiated among multiple social groups. In Robbie Hart's (Missouri Botanic Garden) paper, we followed the problems that emerged when his team asked their Naxi informants around Yulong Xueshan in Yunnan, China to list and characterise sacred sites. Although the results were illuminating, to say the least, they revealed strong distinctions within the Naxi community as well as awkward points of encounter between Naxi and others. Hart pointed out two especially difficult examples. First, tourism in the Naxi region generated wealth but it also drove the commodification and consequent ossification of Naxi culture by the Naxi themselves for consumption by tourists, government officials, and incomers. Second, ritual romantic suicide sites, which are a distinct category of Naxi sacred site, posed both descriptive and ethical problems for scientific analysis. The strong voices of Naxi as authors and informants in the paper meant that these difficulties were neither avoided nor analysed away, but allowed to persist in the paper.

This point resurfaced in the questions, during which one person asked how we might balance consultation and research in determining what, how and where sacred sites are in any one place.

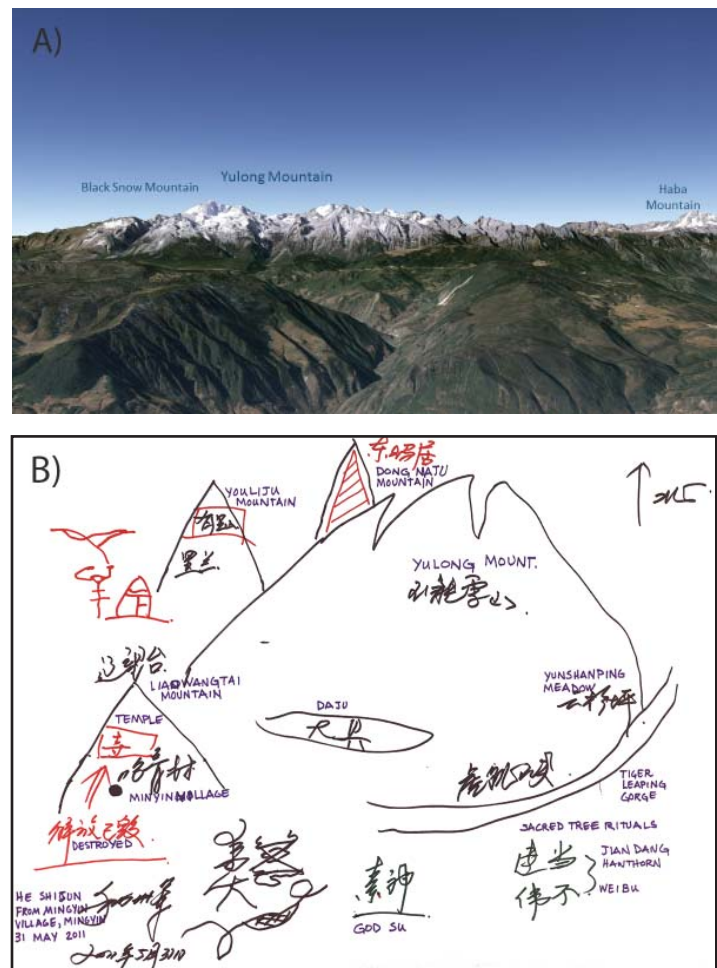
A third recurring feature of the conversation was representation: we were treated to powerful landscape photographs, hand-drawn Naxi maps where the ideographs symbolizing the mountains embodied the form of the mountains, the paintings of Nicholas Roerich, photos of mass protests, selfies on peaks, and sacred diagrams, to name but a few. Between map, word, character, mountain, depiction and conference presentation, we realised that multiple representations did not reduce to a unitary object, but expressed an irreducible plurality and diversity. The power

of representation was both liberating and threatening. Thus, complexity is celebrated in sacred sites at the same time that tourist agencies, extractive industries, intolerant religious communities, or national rivalries seek to limit, appropriate, or commodify them.

The fourth point that emerged was a strong, and very personal, acknowledgement of the positive value of sacred sites in the broader mountain project. Constanza Ceruti (Catholic University of Salta) gave a sweeping autobiographical presentation of her work on sacred mountains in South America, Asia, Central America and North America. Her obvious joy within the photographs, as well as in her presentation, allowed the gathered researchers to gasp, laugh, and hope along with her. It is always difficult to generalise around measurable characteristics of sacred sites, but their capacity to empower, uplift and restore is sometimes lost in the drive to encompass them within usable frameworks—and Constanza's presentation bluntly refused that loss. She ended with a poem, which Fausto Sarmiento picked up as the opening for his paper.

Fausto presented us with an ambitious theoretical and critical synthesis of these dynamics. Without refusing any of these elements—the practical/political, the local/obstinately particular, the hopeful/affective—he proposed a complex but elegant overarching framework of parallel and complementary ecological, environmental, and critical processes, each expressed as a different verbal form of Andean becoming. Although his framework derives from the particulars of the central Andean context, his work demonstrates that these are not incompatible challenges. The same determination erupted at the end of Robert Zomer's paper, when he moved from a discussion of the instrumentality of the sacred in the Kailash project to an ambitious new project looking at sacred mountains in the Altai region.

In sum, our panel showed that a firm commitment to methodological and theoretical honesty and depth does, actually, allow for something beyond a waffly and numinous use of the sacred as a nice thing. The sacred as a category is political both in its genesis and its deployment. Yet local engagements around sacred sites that use participatory methodologies and do not shy away from emotional value do, in fact, lead to measurable and practical results. Well-grounded transdisciplinary research that embraces these tensions offers much greater capacity, stakeholder commitment, theoretical depth, and practical effect for projects around the documentation and stewardship of cultural and biological diversity



Sacred sites in China. A) The region of Mt. Yulong in Southwest China is rich in sacred sites. B) Participatory map developed during research on sacred sites and biodiversity conservation around Mt Yulong. From: Salick, Hart, and Siyu, in review, Local perceptions of biodiversity conservation and sacred sites among the Naxi of Mt. Yulong, Northwest Yunnan, China. Biodiversity and Conservation. Map by He Shijun.

Disaster Risk Reduction

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Disasters take place in the developing and developed worlds and are especially relevant in mountain areas, both because of the naturally more complex geomorphologic character and because mountain areas typically have less development and more vulnerability to disaster risk. Thus, research about disaster risk in these areas is especially important.

Natural, human-induced, and social transformations of mountain systems are intrinsically linked to the occurrence of disasters, which can be regarded as socially constructed processes in time and space. It is indeed the combination of vulnerability and hazards that give rise to disaster risk. Vulnerability is understood in terms of the propensity of people to be affected by hazards as a result of social, economic, cultural and political conditions. Hazards are natural phenomena or processes that may cause the loss of lives, and social, economic and environmental damage.

Reflecting the long-standing paradigm in which disasters are considered as events driven by the natural forces of the Earth, scientific efforts in the last decades have been directed towards the understanding of natural hazards *per se*. Only in the last years there has been an increasing number of studies attempting to incorporate vulnerability analyses and the notion of integrated research into the scientific endeavours.

The international agenda on Disaster Risk Reduction (DRR), specified by the guiding principles of the Sendai Framework for Action 2015-2030, clearly emphasises that "Disaster risk reduction requires a multi-hazard approach and inclusive risk-informed decision-making based on the open exchange and dissemination of data, as well as on easily accessible, up-to-date, comprehensible, science-based, non-sensitive risk information, complemented by traditional knowledge."

The importance of undertaking multi-hazard research was emphasized during the session on Disaster Risk Reduction at the *Mountains of Our Future Earth Conference* in October. Current research efforts focus in particular on landslides, floods, earthquakes, tsunamis and volcanic activity, among other hazards. Approaches developed include high-tech instrumentation, monitoring (Andreas Schimmel, University of Natural Resources and Life Sciences, Vienna, Austria; Pengcheng



La Pintada, Guerrero. Landslide that took place in a small town called La Pintada, in the state of Guerrero. September 2013, around 80 casualties. Photo: Irasema Alcántara-Ayala.

Su et al., Institute of Mountain Hazards and Environment (IMHE), Chinese Academy of Sciences, China), mapping, forecasting, modelling and early warning systems, and also heritage (Richard Johnson et al., School of Society, Enterprise and Environment, Bath Spa University, UK), traditional knowledge and values (Jessica Roberts et al., University of York, UK) as essential means for enhancing the development of community-based approaches (Abhinav Tiwari, Maulana Azad National Institute of Technology, India) for Disaster Risk Reduction.

Since the occurrence of the 2004 tsunami in the Indian Ocean and the 2011 Tōhoku earthquake and tsunami in Japan (not to mention Fukushima), the impact of the concatenation of hazards (Alton Byers, University of Colorado at Boulder, USA) has been addressed more carefully by scientists, insurance companies, decision makers, and other stakeholders. This brings to the table the inevitability of transdisciplinary thinking and action.

Recent events, such as the Nepal earthquake earlier this year, quite clearly illustrate that in spite of the nature of the hazard(s), the multiple dimensions of vulnerability (Jaroslaw Dzialek et al., Jagiellonian University in Krakow, Poland), determine the severity of disasters. Comprehending vulnerability requires multi-factorial assessments (Teiji Watanabe and Dhananjay



Teziutlán Puebla Mx. Landslide disaster risk in the municipality of Teziutlán, in the state of Puebla. Photo taken, March 2015. Photo: Irasema Alcántara-Ayala.

Regmi, Hokkaido University, Japan) that go beyond the present time and take into account risk drivers by looking at root causes of disasters under forensic investigation frameworks (FORIN: Forensic Investigations of Disasters, <http://www.irdrinternational.org/projects/forin/>).

Increased land use change, population growth, inequality, and environmental degradation lead to the establishment of human settlements in areas at risk (Franny G Murillo-García *et al.*, National Autonomous University of Mexico), playing a role in the configuration of disaster risk in mountain areas of most regions of the globe. Therefore, the lack of adequate territorial

management, solid legal frameworks, and especially disaster risk governance urgently needs to be overcome (Alcántara-Ayala and Moreno, National Autonomous University of Mexico).

Education is one of the non-structural measures that needs to be robustly implemented in the vulnerable communities of the world. As such, both informal and formal educational strategies have been implemented to some extent in mountain areas (Rama Maikhuri, HNB Garhwal University, School of Education, India). These programs aim to improve awareness, preparedness and capacity building. What is more, this approach is being improved nowadays by fostering early analysis of risk perception as a baseline for risk communication.

To a large extent, large disasters (or those with numerous casualties) attract the most attention, both of the mass media as well as of the scientific community. Nonetheless, small and medium size disasters greatly contribute to increasing vulnerability and are permanent obstacles for development. To avoid the generation of new risks, concrete consideration of the construction, impact, mitigation and management of small and medium sized events needs to be put into practice.

Disasters are an expression of a lack of sustainable development, particularly in mountain areas of developing countries. Consequently, the sustainability of a mountain community should be considered as a function of its resilience. Indeed, DRR requires the central involvement of mountain communities (Eric Lindquist Boise State University, USA), as well as the recognition of the factors that drive underdevelopment and hence disaster risk. Similarly, it is essential to recognize that disasters are not natural; rather, they are socially constructed processes. Transdisciplinary and integrated scientific research still has a long way to go....



Teziutlán. Collapse of a house triggered by intense rainfall. The house was located on a drainage area! Took place in August 10th, 2015. Photo: Rubén Acebo-Zárate.

Why are Local Initiatives So Important in Mountain Regions?

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Fundamental changes in economic activities and social organization have led to a shift in the characteristics of place-specific contexts in all part of the world. This is epitomized by the general view that “globalization” is affecting the living conditions in almost all societies, and that local actors are increasingly interlinked with external people and cultures. Nevertheless, it is recognized that local and regional development best describes the actual sphere of action and influence. In consequence, key drivers of growth, such as innovation, skills, entrepreneurship, and social cohesion, are closely linked to governance issues, particularly at the local level.

Taking account of the local conditions is extremely important in mountain contexts, where challenges and opportunities for economic activities and social development may vary significantly at a fine scale. In mountain regions throughout the world, an increasing number of local initiatives is being developed. This development has been inspired by area-based partnerships and various financial instruments promoting economic development. In a context of particularly high environmental sensitivity, sustainable development and the preservation of natural resources is critical for finding strategies that simultaneously enhance local assets and strengthen social, environmental and economic development in mountain regions.

At the conference *Mountains of Our Future Earth*, these issues were addressed in a session on “Local development initiatives and institutions/governance”. The three conveners of the session (Thomas Dax, Thomas Streifeneder and Thomas Kohler) suggested the topic of the session because it is (or at least should be!) a priority research field for mountain areas. In the call for papers, they highlighted three main aspects: the role of raising awareness and participation, the need for using collective management and cooperation, and the relevance of elaborating appropriate institutional settings and processes of regional governance to enhance the potential of mountain regions. In total, 15 presentations from all over the world addressed different aspects of this theme and underpinned the idea that local development is at the core of regional actions in European as well as in non-European mountain contexts.

Beyond the different regional contexts expressed by the wide geographical scale of presentations, the main topics and messages of the session contributors highlighted the great diversity of aspects relevant in different regional contexts. Moreover, many themes discussed by the session contributors are relevant to other regions and provide interesting case studies in different contexts. The presentation of local development themes is often based on the historical development of local or regional management arrangements and institutional experiences. In my view, the wide scope of issues and approaches also underpins some of the fundamental aspects for local development.



Source: Climbers Paradise (LEADER activities in Tyrol); <http://www.climbers-paradise.com/quicknavi/images/>

Local development addresses the need for policy intervention and action at a fine geographical resolution, focusing on issues specific to the local context while at the same time reflecting international development and experience in the area. Regional development research has addressed this dual perspective and has strongly emphasized that “local” is not an end unto itself, but rather a means to enhance the quality of life, reduce social and territorial inequalities and contribute to social cohesion (Pike et al. 2006). Local action therefore aims to overcome the challenges of “lock-in” situations in peripheral regions with limited access and low population densities. Local action works toward achieving critical mass and raising the quality profile by enhancing specific forms of collaboration and cooperative structures (Zeuli and Cropp 2004). The most interesting lessons highlighted during the conference session with regard to these dimensions are:

- The neutral term, local development, has different connotations in different cultural contexts. It is therefore crucial to work at appropriate scales and take account of linkages to other spaces and relationships to higher scales.
- In practical work, governance issues are increasingly important. Many areas lack the appropriate institutions to support their local development aspirations. Institutional changes are often required and have to be seen against the backdrop of an evolving multi-level governance system.
- Although the institutional framework is certainly influential for the implementation of initiatives at the local level (Rodríguez-Pose 2013), the most crucial aspect is to involve the relevant actors who are open to participatory processes and creative ideas. This includes realistic views about the limitations of the actor groups addressed, the scope of different perspectives of these actors (and actor groups), the limitations of existing power relations, and the effects of empowerment strategies (e.g. increasing the participation of women).
- Local development is about realizing innovative action (within the evolving contexts referred to above). This can only be assessed using qualitative methods and by enabling an enhanced understanding of the role of trust and cooperation between different actors and the value of institutional involvement.
- Innovation is often understood, in a misleadingly restricted way, as primarily technical innovation. However, for many local initiatives, societal challenges are core and social innovation aspects are pivotal.
- Local development inevitably requires the combined analysis of the different stakeholders, the local economic and environmental constraints, the cultural context, and the institutional setting. It also has to take into account the relationships between different localities and between the local and higher levels of development and administration.



Source: Baumkronenweg Kopfung, Upper Austria, <https://www.holidaycheck.at/pm/bilder-videos-baumkronenweg/a1c580c5-1b7e-3c55-b958-b15055d2fcd5/-/m/picture/mediaId/992f8fef-65cc-3fd3-9843-d3dd1c9272cb>

The focus on local initiatives in mountain development reflects the need to address specific challenges and to facilitate learning processes that support enhanced local decision procedures. Success in these processes depends on transformational changes that would be enhanced by the assessment of sustainable development in mountain regions and activities.

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Source: Vorarlberger Wiesenmeisterschaft (competition of pasture management in the province of Vorarlberg, Austria), www.vorarlberg.at

Glacial Retreat

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As the organizers of the Perth III Conference noted, mountain areas occupy 24% of the Earth's land surface; they are home to 12% of the global population, and another 14% of the population lives in their immediate proximity. Globally, mountain areas are vital sources of water for agricultural, industrial, and domestic use. In an urbanising world, mountain areas are key locations for tourism and recreation; some include major urban areas (Fig. 1).

However, mountains are among the most disadvantaged regions in a global perspective: they are among the regions with the highest poverty rates, and among those most vulnerable. Vulnerabilities range from volcanic and seismic events and flooding to global climate change and the loss of vegetation and soils because of inappropriate agricultural and forestry practices and extractive industries. Mountain regions are thus key contexts for sustainable global development, which is also recognized in the new Sustainable Development Goals. The vital links between mountain and lowland systems are increasingly recognized in global and regional policy debates and action, and provide the context for the conference.

Glaciers will play a crucial role in climate-related vulnerability in the coming decades, and several presentations at the Perth III Conference focused on the study of glaciers and their changes. Glaciers make global climate warming visible: they may serve as thermometers – in the form of ice cores that can be studied to track past climate – or as visible object of climate change: everybody can see the evident retreat of glaciers. Dirk Hoffmann demonstrated this through repeat photography of glaciers over decades as part of a transdisciplinary project of the Bolivian Mountain Institute (BMI).

Interestingly, glaciers in Bolivia showed relatively small changes since the end of the Little Ice Age (ending in the 19th century) until the 1980s. Since then, there has been a rapid change. Where ski competitions on Chacaltaya glacier took place in the 1970s, the ice is gone today. Other glaciers in Bolivia show big retreat over the last years, too. With the expected El Niño event in 2015/16, the impact could even be devastating as less precipitation is expected during such events – the glaciers will lack their essential nourishment. For large parts of Bolivia, glaciers symbolize global warming and climate change.



Figure 1. The former ski resort at Chacaltaya mountain near La Paz. A. View in 1985 while the resort was still operating. B. By 2012 the glacier is melted away, and the ski resort was abandoned in 2001. Photos: H. Stache.

Glacier data from Bolivia are in line with the global trend. As presented at the Perth III Conference, glacier decline in the first decade of the 21st century has reached a historical record since the onset of direct observations (Fig. 2). The glacier data that have been collected by the World Glacier Monitoring Service clearly show that glacier melt is a global phenomenon, and will continue even without further climate change. According to these data, the current rate of glacier melt is without precedence at global scale, at least for the time period observed and probably also for recorded history, as indicated also in reconstructions from written and illustrated documents. This impressive dataset of global glacier changes has been compiled over 120 years, together with National Correspondents in more than 30 countries and thanks to the labour-intensive fieldwork, sometimes in harsh conditions, of thousands of Principal Investigators who measured “their” glaciers.

A new study has investigated the effect of mineral dust on the surface of Djankuat glacier, Caucasus. It was found that particles were transported over thousands of miles, e.g. from the Sahara, before being deposited on the glacier. Using ground-based and

satellite measurements, Maria Shahgedanova and her team showed that desert dust is present on 50-70% of the snow-covered area in the Caucasus Mountains, which highly affects melting due to at-surface radiative forcing. Thanks to satellite data, such investigations can now be extended to other regions, e.g. Central Asia; another talk by Christiane Maier and colleagues focused on the use of the isotopic composition of water in the River Gunt in Tajikistan to establish the sources of water, i.e., precipitation, ground water or melt water.

From discussions at the conference, it is clear that there is a lack of mountain-specific data and information at global, regional, national and local levels, which hampers the generation of mountain-relevant knowledge and impedes advocacy work. However, glacier studies presented at the conference gave good examples about how to contribute to a better monitoring of mountains, and of the rapid changes that are going on there.

This text originally appeared on GlacierHub.org

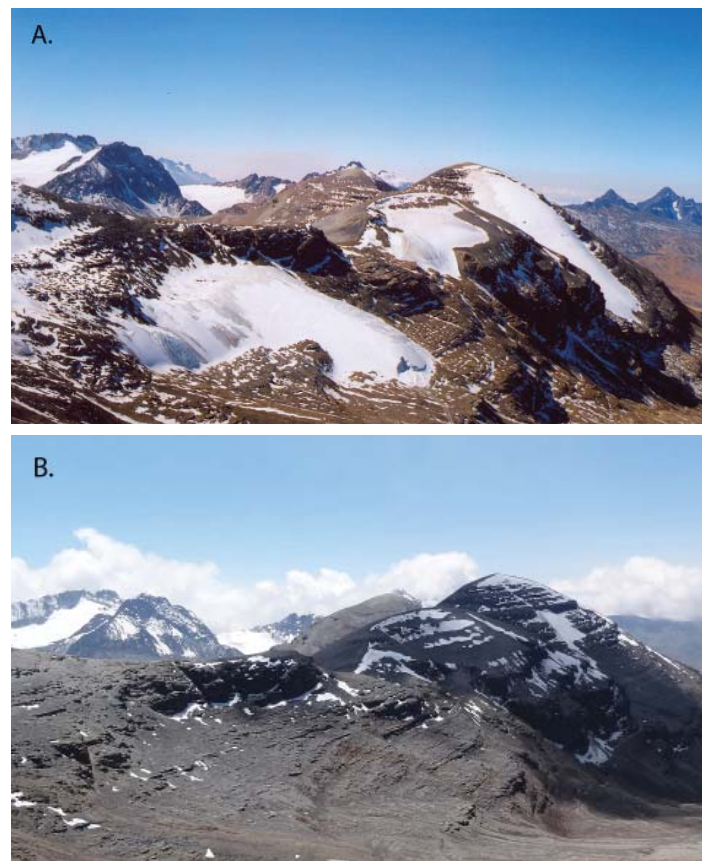


Figure 2. Cerro Chiar Kherini, seen from El Chacaltaya. A. 1995, Photo: H. Stache. B. 2012, Photo: BMI.

Arctic and Alpine Treeline Ecotone Dynamics

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The transition zone in upper mountain and arctic environments from tree to treeless vegetation is known as the treeline ecotone. This ecotone, visible to mountain visitors (and airplane travelers) worldwide, has long fascinated scientists for its sensitivity to climate change: during prolonged cold intervals treelines retreat down in elevation (alpine) or south in latitude (arctic), and vice-versa during warm intervals. Despite this general observation, specific correlates of treeline response to climate eluded detection until the comprehensive studies of Christian Körner and his colleagues demonstrated that the key variable for the transition from upright trees (> 3.5 m) to alpine vegetation was a threshold temperature ($\sim 6.5^{\circ}\text{C}$) during the growing season. While this threshold appears to govern response worldwide, from equatorial mountains to arctic tundra, many treelines demonstrate variable responses in the face of warming or cooling climates. These include lags in response, no response, shifts downward, changes in community composition and dominance, etc. The many and variable responses relate to interactions of climate with regional environmental conditions—such as substrate, disturbance, and herbivore interactions—that modify local response relative to the

“pure” thermal limit. Further, the role of recruitment (emergence of seedlings), and development of seedlings into trees (e.g., trees ≥ 3.5 m), is an important and little known process in the dynamics of treeline ecotones. Thus, although a primary regulator has been identified (temperature), the vagaries that modulate local response to climate remain subject to inquiry.

To encourage research on these questions, we have been working for several years to promote integration of scientists and establish a network of arctic and alpine treeline ecotone scientists. We convened the sessions at the Perth III conference as another opportunity to bring together researchers with common treeline interests and highlight evolving research in the field. We received 47 abstracts on the treeline ecotone theme, which resulted in three oral sessions and a poster session. We grouped the sessions into themes based on treeline movement, reproduction and seedling recruitment, and competition and ecosystem interactions.

Key issues that emerged in the session on treeline movement included a reminder of the importance of standardized definitions



Treeline ecotones in the White Mountains (foreground) and Sierra Nevada (background), California. Photo: Connie Millar.

in the discussion of the treeline ecotone, e.g., treeline (upright trees) vs. species line (krummholz elevation) and the importance of types of control (climate stress-related vs. disturbance-related). While growing-season temperature still emerges as a primary control on treelines, the role of the monsoon appears important, at least in the Himalayas. Other talks on regional and local aspects of treeline dynamics included the role of microsite characteristics (e.g., facilitation), the high diversity of Andean treeline communities, and the role of anthropogenic influences on treeline position. Spatial statistics were presented as important new methods for assessing treeline dynamics, as well as a potential platform for integrating diverse kinds of treeline research.

The session of talks about the role of recruitment in treeline dynamics highlighted further new methods emerging to tackle the complexity of responses, as well as early results from their application. The Global Treeline Range Experiment (G-Tree) promotes a simple and standardized plot method for teasing apart diverse controls on seedling establishment. The protocol is readily applied at treelines of many types and locations. Early results suggest that seed availability and seed predation are important factors governing recruitment. Climatic controls on the multi-year process of cone production-seed development-germination-seedling establishment emerged as critical for development of new cohorts within and above the treeline ecotone. These factors are analysed from observations of natural variation, modelled climate conditions, and increasingly through the use of experimental manipulations—passive to highly instrumented—of thermal and moisture regimes. Long

lags in response, and the strong role of moisture emerged as important factors in regeneration success. Genomic analysis is an emerging new method with strong power to assess and identify contributions of different provenances to above treeline recruitment. The presence of exotic pathogens, as exemplified by white pine blister rust in North America, further impedes successful establishment of recruits across the ecotone.

Contributions to the session on competition and ecosystem processes highlighted the challenges, complexities, and thus dearth of information about these topics. Herbivory is a biotic aspect that modulates local responses of treeline in many parts of the world—what little is known about herbivory suggests that it can play a key role in the patterns of treeline development. Soil nutrition, especially the availability of nitrogen, similarly alters the local responses of trees at treeline.

In addition to oral and poster sessions, we convened an informal lunch discussion with interested treeline researchers to consider opportunities for improving coordination. Three efforts to stimulate integrated treeline research were outlined, including a nascent program lead by Maaïke Bader (University of Marburg), the European effort under the “COST” program, and our own efforts for North American integration (Dave Cairns, Lara Keuppers [Lawrence Berkeley National Lab] and Connie Millar). Harald Bugmann (Swiss Federal Institute of Technology) urged the group to consider an opportunity to develop an international network through funding from the European Science Foundation.



Alaskan treeline ecotone on the Kenai Peninsula. Photo: Dave Cairns.

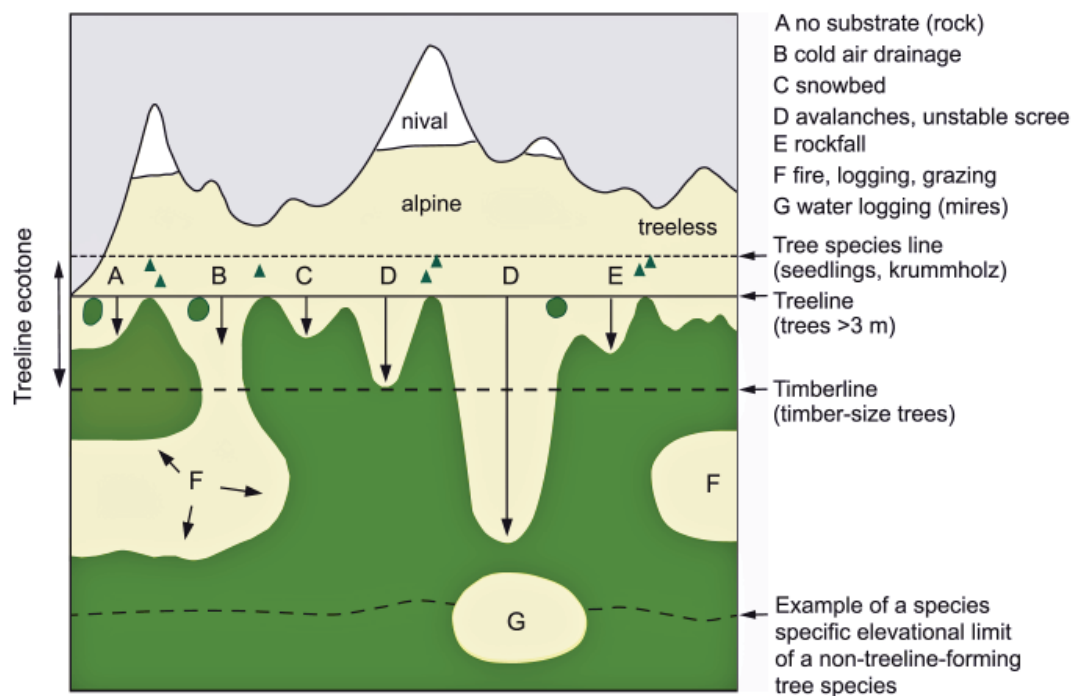
In the spirit of focusing future networking, prior to the informal discussion, we had asked participants to write out a 2-3 key questions or themes they consider to be high priority for treeline ecotone research. The following is a sample of replies from different participants:

- What limits tree establishment above the current treeline?
- What limits growth into tree stature?
- Can recurrent patterns in treeline dynamics be recognised and what factors (e.g. climatic parameters, species traits) determine these patterns?
- Why is radial growth at treeline not enhanced by steadily rising temperatures and atmospheric CO₂ concentrations since the 1950s? Is there drought stress at some treelines?
- Why don't all treelines shift upwards or northwards in response to climate warming?
- We need realistic models based on field data to project treeline dynamics and to quantify how this will impact ecosystem services provided by alpine communities (C cycling and water regulation, biodiversity, etc).
- Can we develop a common protocol to quantify the relative roles of demography, physiological stress, and ecological processes (e.g., competition, facilitation, etc.) in driving patterns at different treelines?
- What data would we need to collect/extract/analyse to categorise/classify treeline 'types' globally, in terms of the composition and form of different ecotones, the conditions that define these ecotones, and the processes driving their treeline dynamics (i.e., can we now start to synthesise, in a quantitative manner, biogeographical/regional differences in treeline dynamics)?
- Similarly, what data would we need to collect/extract/analyse in order to understand, globally, the drivers of treeline change in the context of climatic change and disturbance?
- How do changing precipitation patterns (more rain and less snow) impact treeline ecotones?
- In general there is a lack of experimental studies including multiple sites and regions (G-Tree is an obvious exception); more are needed.
- Site hydrology and treeline advance.
- Bio-physical limitations of alpine treeline ecotone seedling regeneration worldwide.
- Role of disturbance on treeline advance.
- Warming is expected to raise alpine treeline. Why is the response to climatic warming and treeline movement so different in different regions?



Vegetation studies above treeline as part of the international Global Observation Research Initiative in Alpine Environments (GLORIA) program, Carson Range, California. Photo: Connie Millar.

- Is there a universal mechanism to explain the treeline formation?
- Can treeline formation be considered as dry treeline in the grassland boundary in High Asia?
- Ecological theory (niche theory + stress gradient) implies that a multi-scale, hierarchical set of limiting factors toggles the response of an organism, population, etc. to a change in any one of those factors, and so treeline response to climate change across many sites should be expected to be messy and contingent. Is there a coherent taxonomy of the types of treeline change we should expect given regional climate changes, and what diversity in those exists among the treelines of the world?
- How do we measure the set of drivers in the question above in ways, in situ, that allow any meaningful quantification and extrapolation?
- People like to be at treeline, but other than that, why do we really care? What services (ecosystems or others) and values justify our interest in this system when any old ecotone will do?
- Treeline in the tropics (it is not alpine, nor arctic), and there are sensitive and endangered ecosystems in a climate change scenario.
- How applicable are the lessons we've learned from alpine treelines to other ecotones, especially in the context of global change?
- To what extent do the factors that govern dynamics at upper treelines apply to lower treelines? How might patterns and processes be similar/different between the two, with respect to responses to similar factors?
- Some treelines around the world have been studied extensively; others not so much or not at all. We need to fill the gap of our understanding of treelines around the world by studying underrepresented locations in the literature (e.g., Africa, Papua New Guinea, Middle East) and consider the role of cultural factors in treeline dynamics, including traditional ecological knowledge.
- There are a number of ecological factors emerging from treeline studies around the world that appear to impede the response of treeline to warming trends. This would be interesting to explore and synthesize.
- Given the importance of facilitation, some plants clearly play foundational roles at treeline, and this has not been clearly articulated, nor have the implications been fully explored.
- What ecosystem services do treeline communities offer?



Definitions of terms used in treeline ecotone research. From: Körner, C. 2012. Alpine treelines. (fig 2.5) Springer, Basel.

The Perth III Conference: A Student's Perspective

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A young scientist at the start of his or her career is understandably slightly intimidated by the thought of presenting his or her work during a scientific conference. Exposing your work of the last few months to the critical eyes of highly esteemed experts is both frightening and exciting. This was the position I was in a few weeks ago when I gave my first-ever conference presentation, “Satellite-based snow cover monitoring in Lesotho” at the *Mountains of our Future Earth Conference* in Perth, Scotland. Luckily, my presentation went well and none of the dreaded comments or questions was devastating.

But putting the irrational fear of harsh critics aside, what else was taking place at this conference, and how important was the cryosphere in the different presentations?

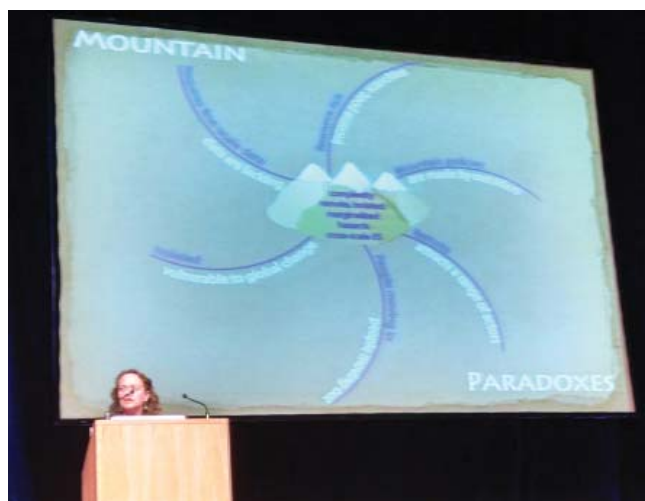
The concept of this conference, was to put the focus on mountains and look at them from through a variety of disciplinary lenses. Thus, the conference covered a wide range of topics, but none in such detail that people from different fields couldn't follow the conversation. Unsurprisingly, then, topics in my field (e.g., snow cover, satellite data, glaciers, etc.) were not covered in every parallel session. Especially on the first conference day, I did not find any snow, ice or glacier related sessions. As a result, I ended up in talks more or less far away from my “home discipline”. Sometimes the talks were mildly

interesting; other times they were unexpected inspirations. I am thinking, for example, of a talk given by Kristen Walsh, who blurred the line between poetry and science by citing Canadian Rocky Mountain Fire Lookouts, who apparently have more artistic virtue than I ever expected. Another example was a talk by Harald Bugmann about “Australian aquatic fauna in European mountain forests”, in which he very entertainingly argued that we as scientists must expect the unexpected, and cannot discard everything outside the 95% confidence interval because shocks are unpredictable.

As a young researcher, one of my key realizations during the Perth III Conference was that it is by no means a bad thing to explore topics outside your comfort zone, as Monday's plenary speaker, Julia Klein, encouraged us to do. Over the next two days, I sat in on a few sessions that did indeed have something to do with my home discipline, namely the sessions on “Global degradation of snow, glaciers, and permafrost” and “The role of alpine cryosphere in endorheic basins of the world”. Even in these sessions, I learned about approaches that are radically different from my own. For example, Dirk Hoffmann of the Bolivian Mountain Institute organized an exhibition about a glacier photo archive in La Paz, Bolivia to create awareness for climate change in people normally unexposed to the topic.

And perhaps very fittingly for such a conference, my own talk about using satellite images to monitor snow cover in Lesotho to support water management took place in the session on “African mountains and their challenges”. Thus, my fear of devastatingly technical questions was totally misplaced. Instead, I enjoyed more on-the-ground questions from people concerned about tourism, plant distributions and sustainability indicators, among other things.

In summary, even though the cryosphere was not the central focus of the conference, I still learned a lot—perhaps more than I would have had the conference been about my home discipline! In many respects, it was more interesting and inspiring to be surrounded by people who are enthusiastic about their own fields and can offer new, unexpected ways of looking at mine. Being thrown in at the deep end of academia turns out not to be as scary as suspected, but instead gave me plenty of inspiration, motivation and, of course, confidence!



Julia Klein urges participants at Perth III to explore topics out of their comfort zones.

Global Network of Mountain Observatories: I Don't Know, Do You GNOMO?

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The press release states

A core group of researchers from around the world launched the Global Network of Mountain Observatories (GNOMO) at 3:02 pm (MST) at the conclusion of a workshop hosted by the Rocky Mountain Biological Laboratory (RMBL) in Gothic, Colorado, USA.

All that's true but the first question is always "how do you say that, again?" GNOMO is not nearly as bad as Eyjafjallajökull, but still I want a movie of all the different pronunciations I have heard. I personally say "juhnomo", or maybe "juhNOMo".

The Global Network of Mountain Observatories (GNOMO) is actually the short name for the Global Network of Long-Term Observatories of Mountain Social-Ecological Systems (SES). Every one of those words is important.

GNOMO's been a long, long time coming. Mountain researchers have been complaining chronically about the lack of observations in mountains, usually meteorological but in other disciplines as well, since I started working with the Mountain Research Initiative (MRI). It is a major premise in MRI's foundational document (Becker and Bugmann 2001). The Global Change in Mountain Regions Project of 2003-2005 produced its first product about the need and nature of a mountain observing system (Grabherr et al. 2005). Reading that document again more than a decade later shows that the overall outline of a mountain observing system was already visible.

Fast forward to post-2010. The Global Mountain Biodiversity Assessment hosts a first meeting of alpine Long Term Ecological Research Network sites. MRI's Global Commission meetings emphasize observations and MRI starts planning the first Global Fair and Workshop on Long-Term Observatories (<http://mri.scnatweb.ch/en/events/events-archive/2196-2014-07-16-19,-reno,-usa,-global-fair-and-workshop-on-mountain-observatories-2>) with Franco Biondi and the University of Nevada, Reno. Italian colleagues propose to the Group of Earth Observations (GEO) a project called *A Global Network of Observations and Information on Mountain Environments*, or GEO-GNOME. Just as the Global Fair and Workshop concluded

its very successful run in Reno, the National Academy of Sciences publishes a report on the future of field stations and marine labs (Schubel et al. 2014). We appear to be approaching critical mass for a network of observatories.

If GEO-GNOME is attempting to create a network in a top-down manner with funding from GEO, MRI's approach to GNOMO is bottom-up and focused on community interest. Funding is surely important but without the enthusiasm of mountain researchers, not much will happen.

Soon after the Fair and Workshop, Jeff Brown and Faerthen Felix, managers of the Sagehen Field Station of the University of California (full disclosure: we are skiing buddies) expressed their interest in having the Organization of Biological Field Stations (OBFS) collaborate with MRI on the creation of GNOMO. Together with Ian Billick, outgoing president of OBFS, and Art McKee, University of Montana, we envisaged a workshop that would bring together station managers, disciplinary scientists, sensor and informatics technologists, and artists and specialists in humanities, not to talk about what a good idea a network would be, but rather to specify what we need to do collectively to make it happen. While we did not want to suppress the inevitable discussion of "but what is the question?", we wanted to focus more on the mechanics of developing "a community of practice", one part of which would certainly be an on-going dialogue about the science.

Ninety percent of success is just showing up; for community-based efforts, it's probably higher. Initially, we focused our invitations on those who participated in the Global Fair and Workshop, especially those who entered their site on the MRI map of mountain observatories (Fig. 1).

In the end, we invited around fifty people to Gothic, Colorado where Ian Billick hosted us at Rocky Mountain Biological Lab (Fig 2). From outside the United States, we had confirmed invitees from Japan, China, Nepal, Russia, Kyrgyzstan, Uganda, South Africa, France, Germany, Switzerland, Colombia and Ecuador. As a measure of their interest, all but one, our colleague from Japan, showed up in Gothic – not the easiest place to get to – and he dropped out for sound reasons, and only from this meeting (Fig. 3).

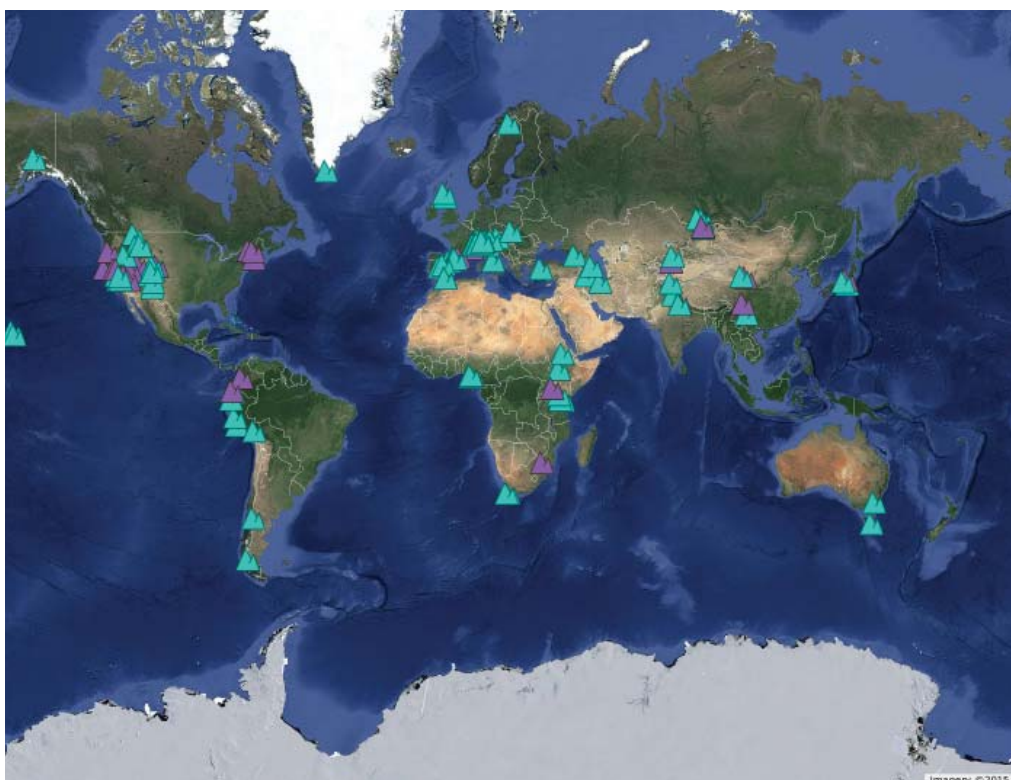


Figure 1. Mountain observatories in MRI's database as of November 13, 2015 (blue) with GNOMO sites (purple).

As in Reno, a major part of the workshop was getting all the participants familiar with each other's sites. Everyone associated with a site gave a short overview; these are now available on the GNOMO website. <http://gnomo.ucnrs.org/index.php/workshop-presentations/>.

As we were interested in the organization of a network, we spent time on an exercise in which people responded with Post-Notes to four questions (Fig. 4):

- Who are our stakeholders?
- What are our values?
- What are our commonalities?
- What are the services that we need?

I focus your attention on “services”, in which data management, communication, best practices, collaboration and technology figure prominently. Similarly, while topics dominate “commonalities”, methods and gradients constitute the second tier of common features. These concerns led to a number of working groups whose on-going work can be tracked on the GNOMO website <http://gnomo.ucnrs.org/index.php/products/>:

1. Data Management

GNOMO approach to data management
Fleshing out GEO-GNOME
Siting and data standards

2. Common Protocols

Protocols for measuring biodiversity
Protocols for measuring social features
Protocols for measuring ecosystem processes
Potential easy, cheap experiments
Protocols for paleo/historical understanding
Comparative analysis using gradients
The role of art and humanities

3. Engaging with Stakeholders

Converting knowledge to action
Outreach and expansion of participation

While there are some funding opportunities on the horizon, the acid test for such a community-based effort is its ability to generate small but nonetheless tangible and pertinent products as proof that there is some there. GNOMO is thus now focused on

- a first try at sharing time series data led by Jon Pollak (Program Manager, Consortium of Universities for the Advancement of Hydrologic Science, Inc [CUAHSI] - and using CUAHSI tools, and
- the development of the Virtual Binder of Protocols, a web-based compilation of methods used to observe different aspects of mountain SESs, and
- framing GEO-GNOME in a manner that includes and complements GNOMO.

Finally, if after all these details you ask yourself, as have many before, what exactly is the point to all this, the GNOMO founding members agreed on the following statement of what they would like see at the end of ten years:

Teams of researchers, covering the range of **pertinent disciplines**, work together in a finite number of sites representative of the **diversity of mountain regions** around the world to develop their understanding of the current structure and function, as well as the longer-term evolution, of **mountain social-ecological systems** using protocols that support comparative analysis, at a detail sufficient to support **forecasts** of likely outcomes, given sufficiently defined boundary conditions, and in ways that **engage a wide range of actors** and contribute significantly to public and private **decision-making**.

So if you, dear reader, think that you would like to engage your site in this new effort and are willing to invest some time in working with like-minded souls on GNOMO, sign up at <http://gnomo.ucnrs.org/index.php/who/>.



Figure 2. It is hard to imagine a better place than the Rocky Mountain Biological Laboratory, Gothic, Colorado to discuss GNOMO.



Figure 3. Founding members of GNOMO.

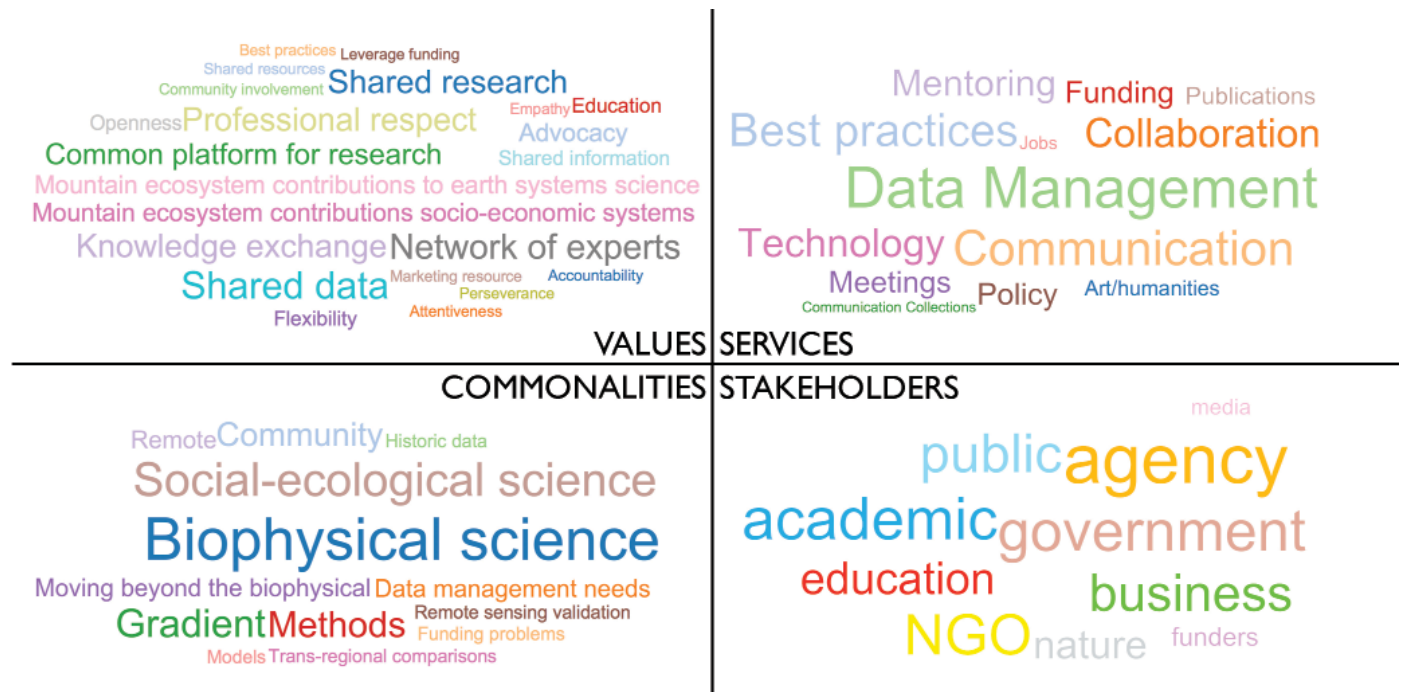


Figure 4. Wordle of topics representing results of the group exercise defining stakeholders, values, commonalities, and services important to GNOMO.

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Assessing Sustainable Mountain Development

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The Sustainability Shibboleth

"Sustainable development is a term that everyone likes, but nobody is sure of what it means." So begins Herman Daly's introduction to *Beyond Growth: The Economics of Sustainable Development* (1996, page 1). Daly, a widely respected ecological economist, goes on to explain that "The term rose to the prominence of a mantra—or a shibboleth—following the 1987 publication of the UN sponsored Brundtland Commission report, *Our Common Future*, which defined the term as 'development that meets the needs of the present without sacrificing the ability of future generations to meet their own needs'."

The Rio+20 Earth Summit in 2012 was (or at least should have been) a good point to pause and take stock: are the mountains of today more sustainable than they were 20 years ago? For many people, the answer may have intuitively been "yes". The data, however, were...well, mostly absent.

Late in 2014, the Mountain Research Initiative (MRI) embarked on a quest to determine what quantitative assessments of sustainable mountain development (SMD) exist. We sent out a call for assessments and received a handful of reports covering an array of regions from a range of perspectives. We also trolled the literature to see what we might be missing.

Our year-long search didn't turn up much in the way of data-driven assessments of mountain development. To be sure, we found many well-developed narratives about the importance of sustainable mountain development, studies that recapitulated existing data, and a number of case studies that focused on a particular element of SMD, such as social sustainability. However, we did not find any studies that quantitatively assessed sustainability from the now-common understanding of sustainability as the intersection of social, economic and environmental factors.

The Capital Approach to Sustainable Development

As noted by Parris and Kates (2003), among others, sustainability has "broad appeal and little specificity...Proponents of sustainable development differ in their emphases on what is to

be sustained, what is to be developed, how to link environment and development, and for how long a time." However, in the now 20++ years since the first Earth Summit, a vast amount of effort has been invested in identifying potential indicators of sustainability, also for mountains. After our year of inquiry, we are satisfied that there is an abundance of mountain-specific indicators to choose from and—importantly—a corresponding wealth of data, even in unsuspected corners of the world (e.g., see Gerlitz et al. 2014, AKDN 2011). What is lacking is a unified approach to measuring sustainable development.

To this end, we suggest a capital-based approach in which sustainable development is defined as non-declining per capita wealth over time (United Nations et al. 2003). The capital perspective is comprehensively explored in the UN Economic Commission for Europe's (UNECE) report *Measuring Sustainable Development* (2009). As noted by the UNECE report, the capital perspective recognizes that wealth per capita is what matters, not just the total wealth of a society. The UNECE defines five capitals:

"... a society's total capital base is seen to comprise five individual stocks: **financial** capital like stocks, bonds and currency deposits; **produced** capital like machinery, buildings, telecommunications and other types of infrastructure; **natural** capital in the form of natural resources, land and ecosystems providing services like waste absorption; **human** capital in the form of an educated and healthy workforce; and, finally, **social** capital in the form of functioning social networks and institutions."

For the sake of simplicity, we reduce these capitals to the familiar three by considering financial and produced capital as elements of "economic" capital, and human and social capital as elements of "social" capital. Of course, some of these capitals are understood better than others, and some are easier to measure than others. Although it may seem more intuitive to measure things like roads or old growth forests, social scientists have made considerable strides in establishing ways to quantify social capital (again, see Gerlitz et al. 2014 or AKDN 2011).

The advantage of using the capital perspective to assess sustainability is that it simplifies the challenge of sustainable development into a question of whether a country's (or a region's, or a village's) total capital base is maintained over time. Essentially, it asks how much money is in the bank, not how fast we are cashing checks. And because it measures whether the three capital stocks are increasing or declining over time, it helps make sense of the inevitable tradeoffs between economic, social and natural capital that must be weighed as development proceeds (UNECE 2009).

Obviously, there are no perfect single indicators for the economic, social or natural capital of any particular mountain region. In fact, we are more accustomed to measuring flows or outputs (e.g., clean water from a watershed, or goods from a factory), than capitals themselves. However, these flows may be good indicators of the capitals, so a realistic assessment may be one that combines capitals (or stocks) and flows. Efforts like Switzerland's Monitoring System for Sustainable Development (MONET) offer one way to reconcile the ideal use of capital data with the more obtainable use of flow data. Ultimately, the MONET system uses 17 "key indicators" that offer a concise view of Switzerland's position and development on the path to sustainable development (MONET 2012). The trends of these key indicators are then depicted in terms of whether the situation is improving, declining or holding steady (Fig. 1).

Thus, the MONET indicator set is broad enough to paint a realistic picture of Switzerland's sustainability status, but can be reduced to a set of indicators that offers a more bite-sized view that can be more readily communicated to diverse audiences. It also provides a framework for quantifying indicators that are not easy to measure. Such a system can be adapted to context-specific factors; after all, the ratio of freight transport growth to economic growth is probably a pretty Swiss-specific factor! However, by using a capital approach to sustainable development, it is possible to see trends in the three capitals, however they are comprised in different contexts.

Whither Sustainable Mountain Development?

Where does that leave us with regard to assessing sustainable mountain development? In the coming year, MRI will be working closely with its Sustainable Mountain Development for Global Change (SMD4GC) partners to agree on a protocol for identifying indicators within the framework of three capitals. In the run-up to the World Mountain Forum in Uganda in October 2016, we hope to develop a handful of comparable but context-specific examples of SMD assessments. The assessments won't be perfect, of course, but they will be useful "proofs of concept"

that will pave the way to more comprehensive, more site-specific, and assessments that are salient to decision makers, scientifically credible, and legitimate in the eyes of the concerned stakeholders.

If you are interested in joining this effort, let us know!

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Are we on the right track?

The assessment of each indicator is represented by one of the symbols below. They result from a comparison of the targeted trend (white arrow against a blue background) and the observed trend (black arrow against white background).

- ✓ positive (towards sustainability)
- ✗ negative (moving away from sustainability)
- ⌘ unchanged

The trends are analysed from 1992 (year of the Earth Summit organised by the United Nations) to the latest available value. For more recent series, the analysis goes back to the year of available data. The start of the analysed period is marked with a ▲ in the graphics if it does not coincide with the beginning of the period shown.

Meeting needs – how well do we live?	Trend Targeted/observed	Assessment
People's health is improving	⬆️/⬆️	✓
Income is increasing	⬆️/⬆️	✓
Convictions for serious violent offences are on the rise	⬆️/⬆️	✗
The unemployment rate based on ILO definition is rising	⬆️/⬆️	✗
Fairness – how well are resources distributed?	Trend Targeted/observed	Assessment
The poverty rate decreases	⬆️/⬆️	✓
Official development assistance is rising	⬆️/⬆️	✓
The wage gap between women and men is gradually narrowing	⬆️/⬆️	✓
Preservation of resources – what are we leaving behind for our children?	Trend Targeted/observed	Assessment
Teenage reading skills are improving	⬆️/⬆️	✓
After an increase, the public debt has returned under the level of 1992	⬆️/⬆️	✓
The investment to GDP ratio is about the same	⬆️/⬆️	⌘
More people are working in science and technology	⬆️/⬆️	✓
The populations of breeding birds are on the rise	⬆️/⬆️	✓
The settlement area required per person is increasing	⬆️/⬆️	✗
Decoupling – how efficiently are we using our natural resources?	Trend Targeted/observed	Assessment
No significant change in the freight transport intensity	⬆️/⬆️	⌘
The public to total transport ratio is increasing	⬆️/⬆️	✓
The per capita consumption of energy is decreasing	⬆️/⬆️	✓
Material intensity is decreasing	⬆️/⬆️	✓

Figure 1. Seventeen key indicators used in the Switzerland's Monitoring System for Sustainable Development (MONET) analyses.

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Mountains for Europe's Future: Putting Mountains on the Horizon 2020 agenda

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The Mountain Research Initiative's regional network "CH-AT", the Swiss Austrian Alliance for Mountain Research, leads a lobbying effort to increase mountain research in the European Union (EU). Our short-term aim is to get more mountain research topics into the 2018-20 calls of Horizon 2020, the EU's current research funding program; our long-term goal is to increase awareness of decision makers about the importance of mountains for all of Europe.



Horizon 2020

The Framework Programmes for Research and Technological Development, also called Framework Programmes or abbreviated FP1 through FP7 with "FP8" being named "Horizon 2020", are funding programmes created by the European Union/ European Commission to support and foster research in the European Research Area(ERA). The specific objectives and actions vary between funding periods. In FP6 and FP7 focus was still on technological research, whereas in Horizon 2020 the focus is on innovation, delivering economic growth faster and delivering solutions to end users that are often governmental agencies.

This is a very big goal for a very small office! We thus called on the Mountain Research Initiative's (MRI) Europe network, which represents over 2,000 mountain researchers from all European countries, for help tackling this challenge. Many people answered the call and expressed interest in lobbying for mountain research within the European Union. These scientists, who are well established within their research communities and have good contacts to the Horizon 2020 (sidebar) contact points in their countries, form the informal "Mountain Research Advocacy Network". In two meetings in Vienna and Bern in April 2015, the core group of this network developed an ambitious plan: a strategic paper with the tentative title "Mountains for Europe's Future", which should be ready by early 2016.

The core group conducted an online survey on the importance of individual sections of Horizon 2020, and then drafted first versions of the chapters of the strategic research agenda during a writing retreat in Switzerland in August 2015. The drafts were presented to the European research community in two feedback rounds. In a first round, we made the thematic chapters available via an online sharing platform, while in the second round we discussed them with the participants of a Roundtable at the conference *Mountains of our Future Earth* in Perth, UK, on October 5, 2015.



Nikolas Katsoulakos, National Technical University of Athens, is content with the time-line developed at the planning meeting on 9 October 2015.

The document concentrates on six strategic research areas that correspond to the Societal Challenges as defined in Horizon 2020:

- Health, Demographic Change and Wellbeing
- Food Security, Sustainable Agriculture and Forestry (...)
- Secure, Clean and Efficient Energy
- Smart, Green and Integrated Transport
- Climate Action, Environment, Resource Efficiency and Raw Materials
- Europe in a changing world - inclusive, innovative and reflective Societies

Each chapter starts with a brief rationale of why mountains – and the corresponding research activities – are important for tackling a specific European challenge. Or, put differently: How is inclusion of mountains in future calls in the European Commission's (EC) interest? By including the rationales, the editors want to reiterate the well known fact that the importance of mountains far exceeds their geographical extension.

The next step is to prepare an advocacy event in Brussels in spring 2016. This event will (only) be as good as our network of advocates who attend and then spread its message! The advocates for mountain research can be found in the EC's Directorates General, in the Horizon 2020 Program Committees, in national offices in Brussels, and in other Brussels-based organizations, such as EUROMONTANA or ERRIN.

Building on existing relationships and establishing new ones is the big challenge for the *Mountains for Europe's Future* team in the next months. Succeeding in this challenge is even more important to the accomplishment of the whole effort than finalizing the strategic research agenda as such. If we succeed, our “recommended research activities” might actually be taken into account within the Horizon 2020 consultation process, and might then influence the 2018-2020 work programs.

We are doing our best to be successful, and we are doing our best to present a role model for similar efforts in other parts of the world.

Websites of interest

CH-AT, the Swiss Austrian Alliance for Mountain Research: <http://www.chat-mountainalliance.eu>

Summary of the results of the Horizon 2020 survey: <http://www.blogs-mri.org/?p=565>

Roundtable “Maximize the mountains profile in Horizon 2020”: <http://www.chat-mountainalliance.eu/en/events/102-ch-at-roundtable-at-perth-iii.html>

Horizon 2020 Societal Challenges: <http://ec.europa.eu/programmes/horizon2020/en/h2020-section/societal-challenges>

Euromontana: <http://www.euromontana.org/en/>

ERRIN: <http://www.errin.eu/>

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One of the working groups at the roundtable “Maximize the mountains profile in Horizon 2020” on 5 October 2015.

Perspectives on Urban Raptor Research from the Reno Hawk Project

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The Reno-Sparks urban area in Nevada serves the Great Basin as a habitat island primarily created by its water diversion and distribution, increased energy in the ecosystem (e.g. birdseed), and physical alteration of the landscape creating many enclaves of diverse microniches. Its situation, lying at about 1370 m against the Sierra Nevada to the west, the Virginia Range to the east, and along the Pacific Flyway migration route, adds to the area's island-like presence in the Great Basin. The result is a region containing complete habitat for raptor life histories and sustaining one of the densest urban raptor assemblages in the Great Basin.

Starting from basic scientific questions about urban development gradients and apex predators, the Reno Hawk Project researches how Red-tailed Hawks (*Buteo jamaicensis*) are changing their breeding ecology relative to urban density represented by metrics that include both the built environment and human presence. This article will review some of the preliminary findings from 2015 regarding population figures, nestling diet, and public engagement, while exploring the framework of the research.

Some Notes from the Nests

In 2015, the project's first season, we encountered some unexpected population figures. In the Reno-Sparks urban area we documented 62 nests used by Red-tailed Hawks and had a nest success rate of 85.5%, which is slightly above – but close to – the national average in various habitats (Orians and Kuhlman 1956, Gates 1972, Mader 1982, Stout et al. 2006). Additionally, our fledge rate of 2.23 chicks/nest (including failed nests which fledged 0 chicks), was high compared to an average of 1.25 for other studies (Orians and Kuhlman 1956, Gates 1972, Minor et al. 1993, Stout et al. 2006). Accompanying these healthy reproduction figures was an exceptionally high egg-unhatch rate of 14.3%. To put this in context, unhatch rates usually hover around 5%, or 9% during high-stress years. Though the cause of this is unknown and we did not collect eggs this season, we propose that either the recent drought desiccated the membrane inside the shell causing the yolk to bind to the shell or levels of some toxin are dangerously high in the urban area inhibiting development.

Nest Camera Use and Prey Items

To accompany the researcher and volunteer-citizen observations, we installed 24 Moultrie wildlife cameras positioned at the nest (Fig. 1) to record various aspects of parenting and nesting behavior – one being prey items fed to nestlings. The wildlife cameras captured one photo per minute from 6:00–11:00 h at 4-mp resolution which proved sufficient for data collection, yet we do not need to revisit the cameras once they are deployed until after fledging. It should be noted that not every camera functioned perfectly and, unfortunately, one camera caused the adults to abandon the nest; however, this was not the closest camera to the nest, in the nest entrance flyway, nor did it differ



Figure 1. Nest camera atop a ball-park light pole in Reno during the 2015 nesting season.

from other installations in any way. Additionally, the nests with cameras on them had a higher fledge rate than those without cameras and while this has occurred with nonraptorial birds for various proposed reasons, we are unsure why this is the case in our study (Buler and Hamilton 2000, Schaefer 2004). During our first year we captured 206,700 images documenting over 3000 feeding events, and 12 species from three taxonomic classes delivered to the chicks. Prey composition consisted of 59% Mammalia, 17% Aves, 5% Squamata, and 19% unknown (Figs. 2–5).

While raptors are often the culprit of killing livestock, earning themselves cultural representations such as the globally popular name “chicken hawk” or generating “frustration killings,” we documented no domestic animals delivered to the nest for chick consumption. Remains of domestic prey may have been deemed “unknown,” or hawks may have consumed domestic animals away from the nest outside of our view. It is more likely that domestic animal depredation will occur outside the breeding season (especially during droughts or near the end of summer when there are more young and less experienced birds hunting).



Figure 2. Ground squirrels helped this nest fledge four chicks; however, the nest came down this fall much to the disappointment of the residents.



Figure 3. The male delivers a struggling gopher snake to a nest with three chicks and two unhatched eggs. This was the largest clutch discovered in our area.

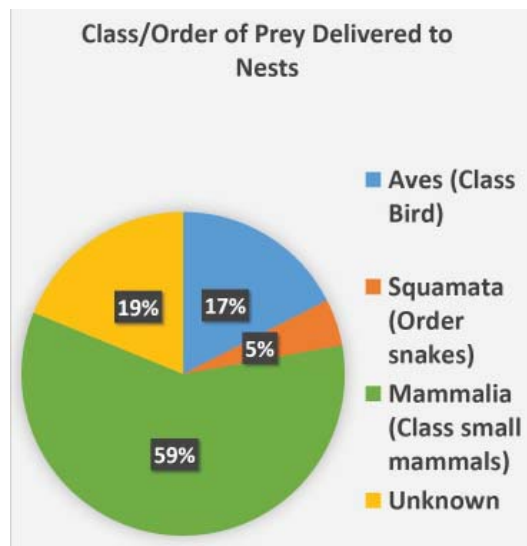


Figure 4. Prey deliveries by taxonomic class in 2015.

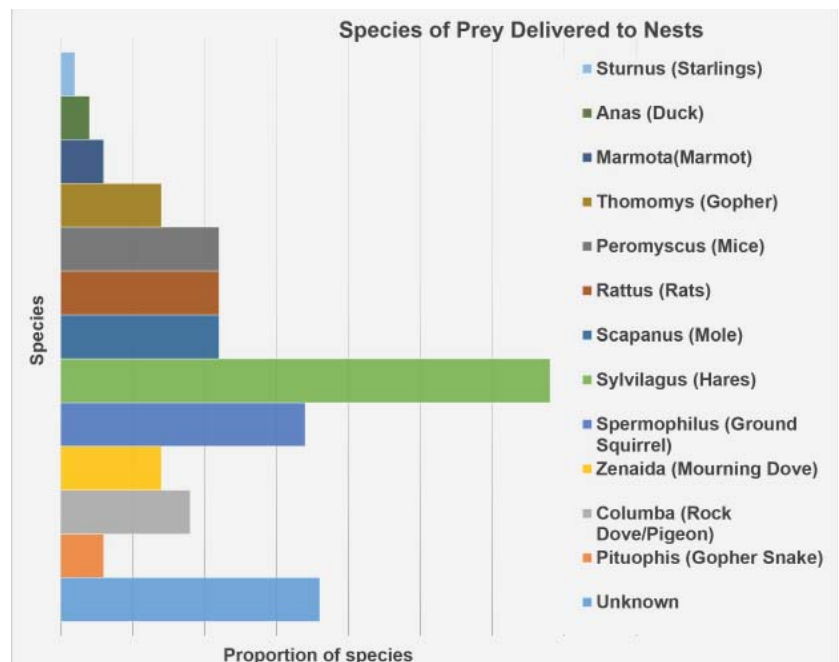


Figure 5. Proportion of prey deliveries by species.

Public Engagement in the Research

During the nine months of nest searching and field protocol design prior to the 2015 breeding season, I realized that the project needed: 1) an educational outreach component as it is generally not the urban structures themselves that prevent raptors from living in an area but the human activities and disturbance – which are most often unintentionally disturbing to the hawks and may be mitigated if an education medium was present, and 2) a community engagement platform as I discovered that residents were excited and fascinated about their local raptor populations, and were interested in participating in the project. Therefore, I designed the project to incorporate a broad spectrum of public interests. Some of the ways that the public can participate in the project include the following: submit a nest location, allow us to monitor on their property, collect as many photos from our nest cameras as desired, come to one of our three project presentations at local venues per year (in addition to the three other related local raptor field exhibitions in our first year), meet a researcher at a nest site to view the hawk's parenting behavior during an observation period, or become trained to collect observational data without a researcher effectively becoming a citizen scientist. This range of participation options aims to eliminate the byproduct of exclusivity from projects that only involve the public for the data collection portion of the research when all

residents may not have that ability. In the end, 30 of our nest observation periods were attended by the public (Fig. 6). People of varying ages and experience levels joined us to observe hawks at their nests, collect data, or simply ask researchers questions.

The Near Future?

As winter approaches the Red-tailed Hawks migrate south, arrive from the north, or stay here, and I focus on project logistics indoors. The winter will be spent seeking funding for the spring season, reviewing our protocols, amending them where necessary, and conducting community outreach and engagement. I will also be recruiting and training another field crew for this spring beginning in December and January. This fall at the Raptor Research Foundation Conference in Sacramento, CA the project had three poster presentations: two of which were presented by undergraduate interns who hope to conduct research and potentially attend graduate school in the future. It was a great experience for all and many positive relationships formed with other researchers and enthusiasts.

Background and Funding

The Reno Hawk Project is a part of my dissertation research at University of Nevada, Reno (UNR) under Dr. Scott Bassett. The project will run from 2014–2017 unless carried on by someone else. Our first year was funded primarily by Geodactics, Researchers Implementing Conservation Action, and our total budget was ~\$5,500. Nest camera installations were conducted by Josh Snook from Joshua Tree Works tree-care company (Josh is also a trained wildlife scientist) and myself. Field work was conducted by six volunteer field interns from Truckee Meadows Community College and UNR.

For more information, visit: RaptorsofReno.org

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Figure 6. Linda Rhodes, local resident and long-time hawk watcher, helped monitor hawks around the area for the duration of the study.

Rain-on-Snow Flood Module for High-School or Undergraduate Students

Nicholas Wayand

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Rain-on-snow events are familiar to the residents of western North America, and typically involve a warm winter storm (atmospheric river) approaching from the Pacific Ocean, which dumps large amounts of rain at elevations above the normal snow-line (Fig. 1). These events are often associated with large floods, but sorting out the contribution from rainfall versus melted snow is difficult given sparse mountain observations. Public misconceptions of how much snowmelt matters for flooding, and what causes the snow to melt, are easily found in newspaper articles. For example, after the June 2013 extreme rain-on-snow flood in Calgary, Canada: "...snow gets melted by the rain falling on it and that compounds the situation..." – Global News, June 2013.

But how much actual snowmelt contributes to the flood volume versus rainfall? And does the warm rain melt the snow? These questions have driven a considerable amount of observational and modeling research over the western U.S. (Harr 1981, Kattelmann 1997, Marks et al. 1998, 2001, McCabe et al. 2007, Mazurkiewicz et al. 2008, Herbst and Cooper 2010, Wayand et al. 2015a) and Europe (Singh et al. 1997, Sui and Koehler 2001, Garvelmann et al. 2014, 2015, Rössler et al. 2014)

We have developed a module to allow advanced high-school students or first year undergraduates to address these questions on their own, through use of a simple energy balance model of the snowpack. The module contains three main parts: 1) a YouTube video on the energy balance, 2) slides on the primary components of the terrestrial energy balance and practical problems, and 3) an activity using the Excel snow model to calculate snowmelt magnitudes during a recent flood near Seattle, WA. The module has been developed as part of the larger University of Washington High School outreach program, which hosts multiple climate science modules (<http://tinyurl.com/oqo8ml7>).

The educational snowmelt model was written in Excel to allow a wide audience without prerequisite of any coding language. The model's strength is in its transparency. All equations, meteorological driving data, physical constants, and parameter values are presented on a single sheet so that students avoid working with a black-box model. In effect, the model calculates the daily net energy for snowmelt from each component (net

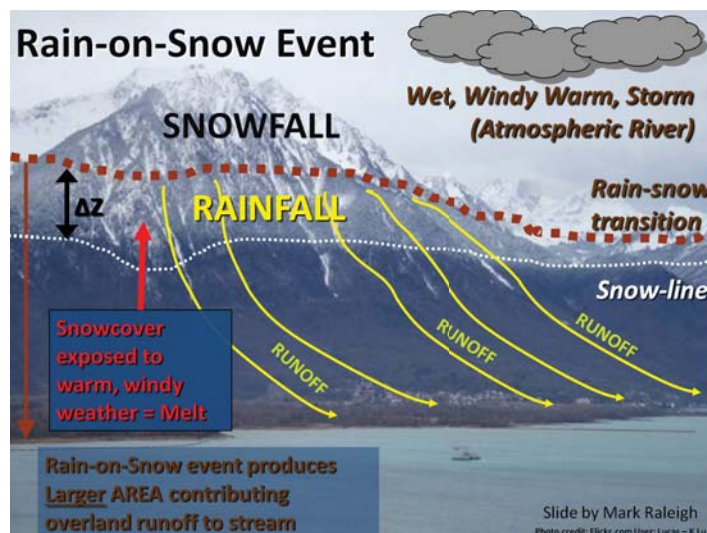


Figure 1. Illustration of common conditions during a rain-on-snow event: 1) High-elevation snowfall level, 2) rain falling over a larger area of the basin than is typical during winter, and subsequently contributing to runoff, and 3) existing snowpack exposed to warm and windy atmosphere driving potentially large snowmelt rates. Modified from slide by Mark Raleigh.

solar, net terrestrial radiation, sensible heat and latent heat flux, ground heat flux, and heat advected from rainfall). We make the assumption that the snowpack is isothermal (0°C) so that all energy goes into melting the available snowpack. The model outputs include the total daily snowmelt and rainfall contributing to flooding, as well as snowmelt from each individual component (Fig. 2). Model inputs are six weather variables (air temperature, relative humidity, precipitation, wind speed, short- and long-wave radiation) that are taken from local observations within the Snoqualmie river Basin for the module activity. These data are freely available at <http://dx.doi.org/10.6069/H57P8W91> as described by Wayand et al. (2015b, *in review*). Live plots of all required input data are also available at <http://depts.washington.edu/mtnhydr/cgi/plot.cgi>, which allows students to easily retrieve current data.

This rain-on-snow module's learning objectives meet many of the wider goals of high-school and undergraduate climate science courses. Most important of these is to familiarize students with

the components of the earth's energy balance, which they do by calculating individual components and identifying the dominate fluxes of energy during different atmospheric conditions. The module also helps students build Excel skills, which are transferable to a wide range of applications. An optional extension of the module is to have students code in the equations for different energy balance components in Excel, thus cementing their understanding of the theoretical equations and building model hypothesis testing at the same time (i.e., did the code I just wrote result in sensible heat flux values that make sense?).

Finally, the activity and data used to drive the model can easily be customized to a local basin/mountain range (if available) to better relate students to the physical process that have a direct impact on their lives (flooding, water supply).

More information and module files can be found at <http://students.washington.edu/nicway/outreach.html>. Please let me know if the module was useful and if you have any suggestions for improving it further: nicway@u.washington.edu

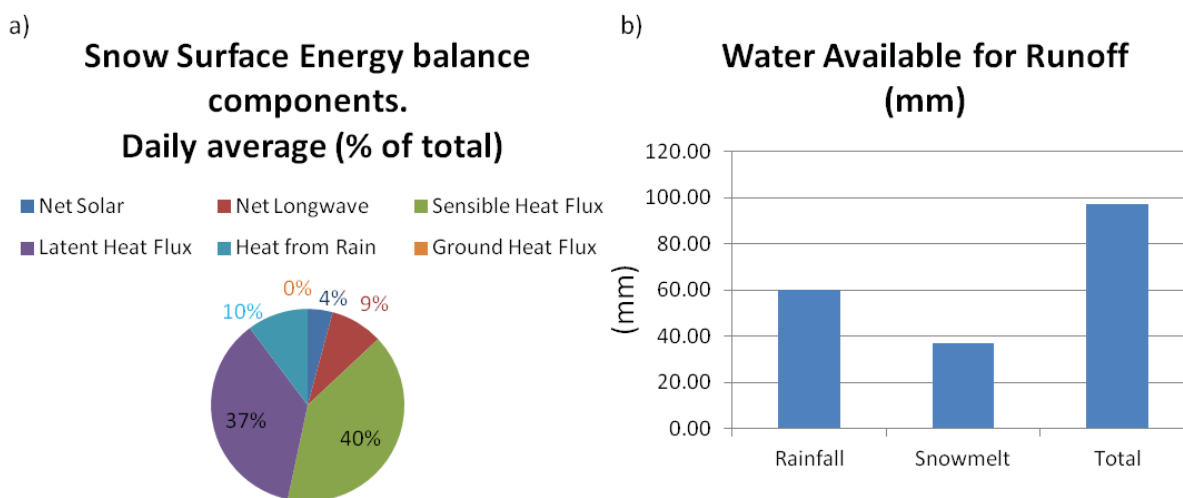


Figure 2. Example output from the Excel snow model. a) Components of the energy balance contributing to snowmelt over one day. b) Comparison of modeled snowmelt to rainfall.

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Castle Lake Environmental Research and Education Program: Home of North and South America's Longest Running, Montane Ecological Study

Sudeep Chandra

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The Castle Lake Environmental Research and Education Program has a long history of basic and applied environmental research activity. Located in Northern California near the town of Mt. Shasta (Fig. 1), the lake was utilized in the early to mid 1900's by the California State Department of Fish and Wildlife to evaluate hatchery fish survival. It was the height of cultural imperialism, fishes (trout, salmon, grayling) were reared at the Sisson hatchery then added to the lake to assess survival. If fishes survived in Castle Lake, then they would be reared and stocked in mountain lakes across the region into the Sierra Nevada.

By the mid century, the evaluations moved away from assessment of fish survival and into lake production. In 1959, Dr. Charles R. Goldman from the University of California at Davis initiated a project to evaluate the factors controlling primary (algae) and secondary (zooplankton) production in the lake (Fig. 2). Goldman used a ^{14}C Carbon tracer method he developed and modified from oceanographers while working on oligotrophic (less productive) ecosystems in Alaska's Brooks Range to quantify primary production in Castle Lake. Little did Dr. Goldman know that his initial measurements would result in over 56 years of ecological collections, which is now the longest running, montane ecological data set in North and South America.

Known for many novel findings, Castle Lake is the first lake site in the world in which trace elements (such as molybdenum) were shown to limit algal primary production. This study by Goldman appeared in the journal *Science* in 1960. Plants and algae require at least 17 essential nutrients for growth often in stoichiometric ratios depending on the taxa. Macronutrients (i.e. C, N, O, Mg, P, S, K, and Ca) are required in large quantities whereas others (Fe, Mn, B, Cl, Cu, Ni, Zn, and Mo) are mainly required in much smaller quantities. Phytoplankton differ from other primary producers in requiring additional nutrients including As, Br, Cd, Co, I, Na, Si, Sr, Mo, and V. Because many of these elements are sourced in the terrestrial landscape, the studies assessing trace element limitation in Castle Lake were some of the first where a relationship was documented between watershed vegetation/ geology and fertility of lake ecosystems. Thus, lake limitation may be landscape dependent, and the research from Castle Lake's watershed suggests an intimate connection between run off, terrestrial plants (e.g. alders), and within-lake productivity.

In the late 1960's, with funding from the National Science Foundation and a special use permit from the US Forest Service, a small cabin-style laboratory was constructed along the shores of the lake. This laboratory facilitated the longer-term monitoring of lake production during ice-free periods and allowed for evaluation of whole-lake experiments to test various ecological theories of the time. In the early 1980's, for example, inorganic nitrogen was added to the epilimnion to quantify its influence to lake production (Axler and Reuter 1996). They found that periphyton (benthic algae) nitrate uptake and denitrification, not phytoplankton assimilation, accounted for 90% and 73% of the depletion of inorganic nitrogen. This study suggested the importance of benthic habitats in controlling nutrient transformation and uptake within lake ecosystems. Consumer manipulations in the late 1980s suggested the importance of behavioral trophic cascades in controlling food web connections and resulting primary production (Elser et al. 1995). This was identified through a reduction of rainbow trout densities, which resulted in compensatory responses to fish assemblages including brook trout and golden shiners, which increased in abundance. This compensation resulted in increased rates of planktivory on one species of zooplankton, *Daphnia*. However, zooplankton shifts in response to discontinuance of trout stocking were more rapid, particularly an immediate increase in a previously rare invertebrate predator, *Diacyclops thomasi*, with other changes to clarity and primary production. Finally, in the early 2000s, research evaluating trophic efficiency and production in relation to consumer dynamics suggest the importance of benthic resources in driving higher level consumer energetics (Vander Zanden et al. 2006). This study, which incorporated an analysis of the long-term data set and some newer data collections, suggested energy is more efficiently passed along benthic food chains relative to their pelagic counterparts even though the open water habitat produces 50% of the algae production from the base of the food web.

Many contemporary ecologists have been trained with the understanding that long-term ecological data can yield important insights into whole ecosystem and community dynamics, particularly in relation to climate induced forcing events. For example, Strub et al (1995) linked El Niño/ La Niña ocean cycling to the thermal heat capacity and subsequent lake

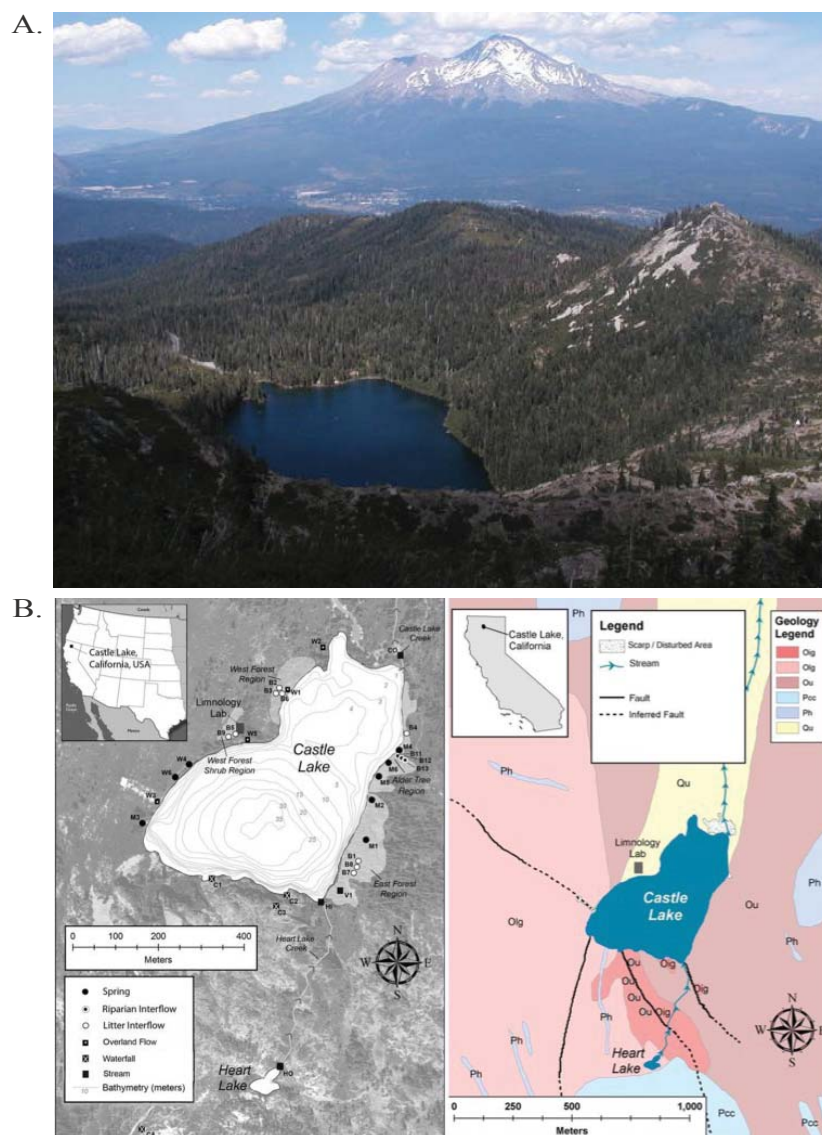


Figure 1. A. What a view! Subalpine, Castle Lake is located west of Mt. Shasta in the Eddy Mountains of northern California. B. Terrestrial ecotypes in the Castle Lake watershed include patches of coniferous forests on medium to low-grade slopes; low-lying shrubs on rocky, steep slopes; large outcrops of steep, exposed bedrock; and alder trees on a medium to low-grade sloped riparian, spring-fed zone. In addition to diverse flora and topography, the geology changes throughout the Castle Lake basin and includes ultramafic partially serpentinized peridotite, mafic calcium-clinopyroxene gabbro, and outcrops of felsic diorite and granodiorite on the ridges.

primary production. Follow up studies, revealed that snowpack, precipitation and other environmental parameters make Castle Lake and other mountain ecosystems sentinels for change. Today, the long term data collections at Castle lake and her sister ecosystem, Cliff Lake, another small mountain lake located in the region, allow for the quantification of the influence of fish consumer and climate to lake biodiversity and function. The collections from Castle Lake have allowed for the determination

of climate change and influences of temporal changes in food quality in the lower food chain of lakes for production at higher trophic levels with published articles in prestigious scientific journals such as *Science*, *Nature*, *PNAS*, *Ecology*, *Limnology and Oceanography* and many more. Of course, this research would not have been possible without support from a variety of funding sources, including the National Science Foundation, McConnell Foundation, and donations from private individuals.

Current and Future Directions; Development of an Art-Science Program

The midterm direction of the Castle Lake Environmental Research and Education Program has been to understand the influence of climate forcing and manipulation of consumers to lake production and biodiversity. In the last seven years we have initiated a whole lake experiment to investigate how fish stocking (or lack of stocking) may influence planktonic biodiversity and subsequent primary production in the shallow, epilimnetic and deeper hypolimnetic production. In addition, there has been a focus to quantify the flux of nutrients from different vegetation structure to the lake as well as the flux of carbon from the benthic habitat to the terrestrial environment. While the team of graduate students, post doctoral researchers, and staff continue the legacy of measurements at the lake (Fig. 3), there is a continued challenge to obtain funding for this kind of place-based research. Similar funding challenges in a time when long-term information from a single ecosystem may not seem as relevant compared to high frequency data collections from multiple locations.

The program directors have had a long term soul-searching related to how to proceed with future funding opportunities and what it means to have a location that enables a place based

understanding of nature. A new goal for the the program is to integrate reflection and understanding of nature into our measurements of the natural environment. This region of northern California is rich with artistic talent and enlightened conversations. Our hope in 2016 is to launch a program that couples an understanding of nature in the wake of climate change and species introductions in the lake with artistic expression.

Training and Teaching the Fundamentals in Watershed Research

The Castle Lake station has been used by a class at University of California at Davis and the University of Nevada at Reno to engage students about the importance of long-term data collections in ecology along with principle methods utilized in watershed to limnological investigations of the environment. Over 1200 undergraduate students have been trained at the station through classes and summer internships. In the past, the station coordinated with their U.S. Forest Service partner and local school districts to promote environmental education of primary and secondary school students. Furthermore, the station has facilitated the graduate studies of at least 50 dissertation and Master's theses, with over 150 publications resulting from this work.



Figure 2. The early years with Dr. Charles Goldman sampling water quality from Castle Lake during an ice covered period.

Field Station Staff and Support

The Castle field station is a small, solar powered laboratory with modest facilities including a kitchen, hot shower, flush toilet, and wood stove. Tents are used for housing staff and students. Road access is available to the lake during summer months (June to November) and occasionally during winter months after plowing. Three to five students and staff operate the laboratory throughout the summer months. The facility has two row boats and all the basic equipment necessary for basic limnology measurements.

Longer term data have been carefully archived and some of the basic data can be obtained at <http://aquaticecosystemslab.org/projects/castlelake/>. The station has the potential for supporting many more classes and field trips in environmental and natural resource sciences (soil, forest, atmospheric, etc.). We welcome students and teachers to join us at the Station!

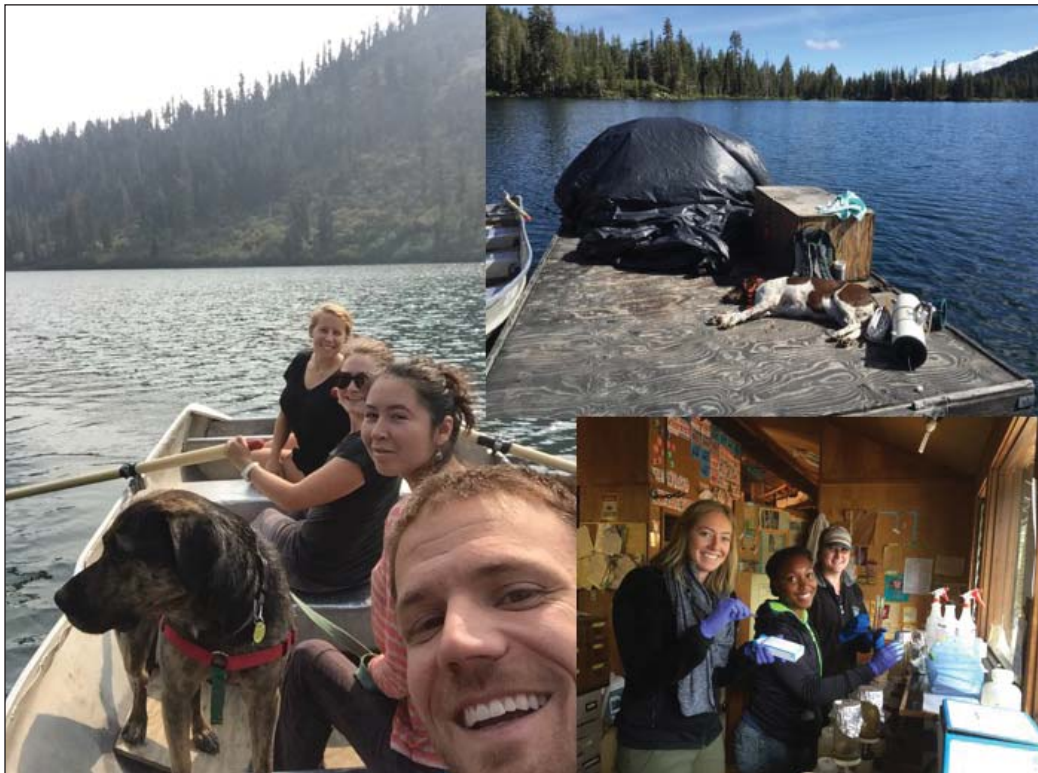


Figure 3. A student and dog selfie (left) while rowing to a raft where experiments are initiated underneath a tarp (upper right). Students processing water samples for chlorophyll *a* analysis (bottom right).



Mt. Hood, Oregon, from near Timberline Lodge. Oil on masonite, by Martha Apple.

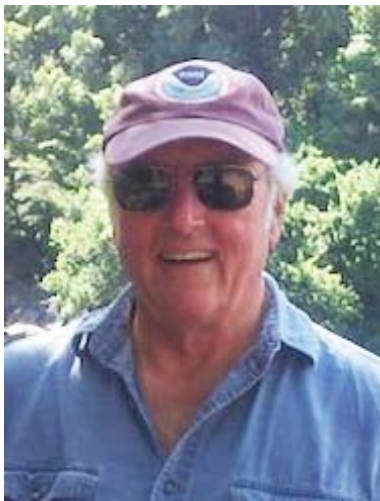


Seracs on Coe Glacier, Mount Hood, Oregon. Photo: Hassan Basagic.

Henry Diaz is one of the founding coordinators of CIRMOUNT and remains an important leader and enthusiastic supporter of the consortium. In 2007 Henry retired from NOAA and has worked since as Senior Research Scientist with the Cooperative Institute for Research in Environmental Sciences of the University of Colorado, and emeritus with the NOAA Earth System Research Laboratory in Boulder, CO. His work continues to focus on hydroclimatic variability with increasing attention to Hawaiian environments and ecosystems. Henry has served on editorial boards for numerous climate-science journals, was Adjunct Associate Professor at the University of Colorado (Boulder) and University of Arizona (Tucson), and Adjunct Professor at the University of Hawai'i at Mānoa (Honolulu). He served on the IPCC Working Group 1 in 1990, 1992, and 1995. Henry is a Fellow of the American Meteorological Society. This fall, I was pleased to catch a few words of wisdom from Henry in the following interview.

—Editor

HENRY DIAZ



Henry at Haleakala National Park on the island Maui, Hawai'i

Connie: How did you first get interested in mountains and their climates? What influences in your early life/training/career were especially important?

Henry: I first came out West on a long road trip in 1973 and fell in love with the landscape, the vistas, and the emptiness. It took seven more years, but I finally landed in Boulder, where I could continue to indulge my aesthetic as well as getting the opportunity to do science in mountains and about mountains. A second big turning point occurred in the early 1990s when Ray Bradley and I started collaborating on mountain climate studies, later including Martin Beniston, now at the University of Geneva. Another bit of serendipity occurred when I met Roger Barry, a well-known authority on mountain climate, at a meeting in Tucson, AZ in 1977. I got my Ph.D. at the University of Colorado in Boulder with Roger a few years later and started working professionally on mountain issues in the 1980s.

Connie: What would you consider to be some of the most important areas of progress in mountain climatology over the course of your career?

Henry: Obviously, the key climate attributes of mountains are the changes in temperature and precipitation over short distances due to changes in elevation. Mountains have always been under-observed compared to lower areas—for the obvious reasons that few people live in the higher regions compared to valleys and large plateaus, and the difficulty of establishing operational monitoring sites on mountains. That lack of observations has hampered our ability to understand the nuances of mountain climates—a situation that continues at the present time. Nevertheless, progress has been made via a number of national and international efforts to monitor climate in high regions and other closely related natural systems like ecosystem functioning.

Connie: In your view what is/are the most pressing questions and topics that need to be addressed in the next decade?

Henry: From the perspective of the future evolution of climate as the world warms due to increasing atmospheric greenhouse gas concentrations, the complex topography presents the modeling and observational communities with major challenges. To be able to adequately simulate climate variables in complex topography, very high spatial resolution is required and that imposes significant demands for computing resources. Some progress has been made, but the lack of validation data to evaluate the modeling results presents continuing difficulties. The lack of resources to enable a global mountain climate observing system represents one of the most critical unmet needs with regards to mountain science in general.

Connie: What strategies do you consider most important (and effective) to bring mountain regions into greater awareness and understanding among policy makers and the general public?

Henry: I think a combination of national and international partnerships encompassing different disciplines has been a goal of several members of the original CIRMOUNT community. That includes the work by Greg Greenwood at the international Mountain Research Initiative, headquartered in Switzerland. However, despite these best efforts, an integrated top-down and bottom-up approach to mountain climate science issues (writ large) along the lines of the polar climate community remains unfulfilled. There are national efforts aimed at confronting climate change impacts on water resources, drought, forest resources, coastal systems, urban systems, agriculture, etc., but oddly enough a high-level champion has not emerged to push forward a coordinated funded approach to the range of problems that may impact mountain communities. I think that perhaps, given the focus on individual parts of the system that are getting attention, as noted, may result in a situation where the sum of the parts might, in the end, equal or exceed the whole.

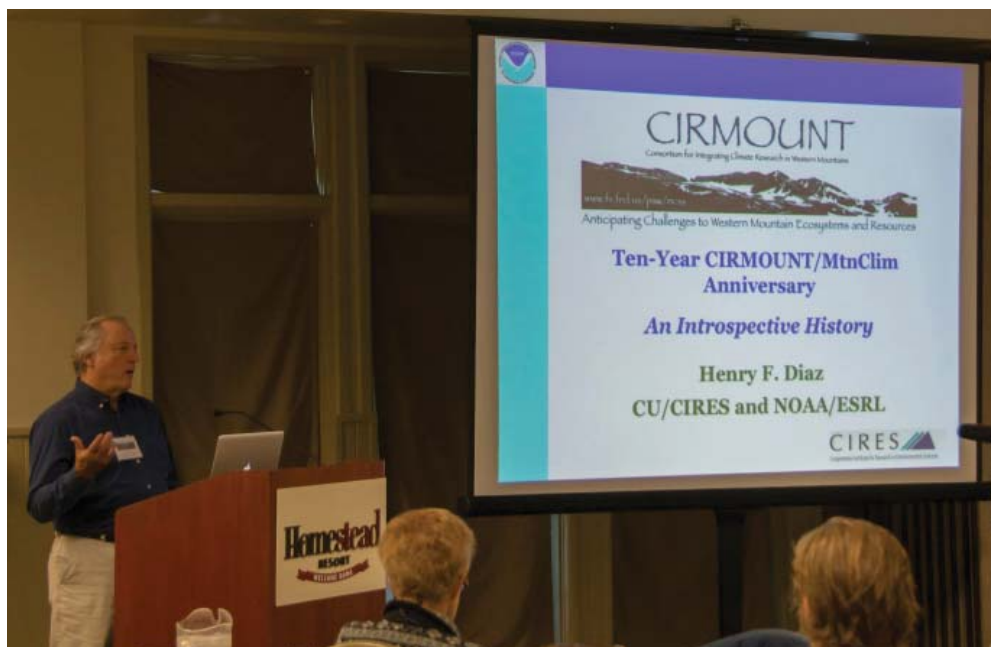
Connie: What advice or suggestions do you have for CIRMOUNT as a grass-roots consortium to be more effective in future years?

Henry: Keep on keeping on! Certainly one sees continuing advances in the scientific and human ecology aspects of mountain regions in the USA and particularly in Europe. Third-world

countries with significant mountain regions and populations are likely to experience even greater impacts from ongoing and future changes in climate. Such high-level partnerships as recently announced between AGU and ESA are good steps in the direction of greater integration of disciplines and hopefully of greater multidisciplinary collaborations.

Connie: What are you up to these days, and what goals do you have now – science, policy, and otherwise?

Henry: Well, as you know, I've been working with some colleagues in Hawai'i on climate change related topics in the Islands for almost a decade. It's been a lot of fun and my involvement with several graduate students and seeing them through graduation has been rewarding. While still formally a part of the Cooperative Institute for Research in Environmental Sciences (CIRES) at the University of Colorado (where I was able to segue to after retiring from NOAA), I've continued to collaborate with colleagues at the University of Arizona (Malcolm Hughes, Tom Swetnam and Valerie Trouet), and Ray Bradley at the University of Massachusetts. Some new avenues of study may be opening now, which might bring me back to an area that I worked on in the 1990s. But the readership will have to wait to learn more about that!



Henry delivered a talk on the work of CIRMOUNT at the 10th Anniversary *MtnClim* 2014 Conference in the Wasatch Mountains, Midway, UT, September 2014. Photo: Scotty Strachan.

In this section, I query members of the CIRMOUNT community for their perspective on a topic of interest. In that we are highlighting the recent international mountain conference in Scotland, I asked several participants to respond to the following question:

What important messages did you take home from the Perth III Conference, Mountains of our Future Earth?

Scotty Strachan, Department of Geography, University of Nevada, Reno, NV

To be honest, I was not quite sure what to expect from Perth III; I came determined not to focus on research minutiae but instead to think about wider integration of my own questions/research directions within the conference context. Specific research talks were not uncommon, but there were some overall threads that came together for me, both explicitly stated by the conference secretariat and generally implied via the sum of my interactions with individuals.



1) The states and fine-scale histories of mountain physical near-surface processes are largely unknown, even in very developed countries. Top-down research/policy/funding initiatives are only dimly aware of this, in spite of the relative importance of mountain systems for society in general. 2) Mountain-oriented scientists worldwide have begun or are initializing in-situ research/monitoring of one kind or another, but these are ground-up in origin and therefore diverge in background scientific/policy motivations as well as scale. There will be a struggle for the many small voices to become one. 3) There is much to be shared in terms of data/practices/alignments across these various ground-up programmes, although many are members of one or more ad-hoc niche networks. Some of these networks have some information communication/sharing-enabling infrastructure and centralization, but most are rudimentary at best. There is a technology-driven organizational vacuum to be filled that traditional ground-up practices or even short-term networking

grants simply cannot address. This gets back to statement #1, where there is no obvious vision being followed by major hard-funding sources to support mountains-specific observation/research. Exploration of space might be the final frontier, but we are going to need a better understanding of the mountainous frontier before we get there! Yes, we have been there, but how well do we know it?

Iris Stewart-Frey, Department of Environmental Studies and Sciences, Santa Clara University, Santa Clara, CA

When we put our multi-disciplinary heads together, powerful synergies evolve. The nexus between population, water, development, biodiversity, climate, and human-wellbeing needs to be understood conceptually and empirically for forging paths towards greater sustainability. We must use rigor, empathy, and imagination. The remoteness of the mountains that we work in makes them vulnerable and hold-outs against change, both biophysical and social, at the same time. We get further if we take an integrated approach to studying and preserving mountains.



When I compare Perth III conference to Perth II, I felt myself immersed much less between the hydrologists and climate scientist, but between social scientists and ecologists and those who have bridged the disciplines. One simple yet powerful moment of revelation came when an anthropologist described surveying mountain people as to which future they want. We have not asked this question enough, where do mountain communities see themselves going?

Hans Schreier, Faculty of Land & Food Systems, University of British Columbia, Vancouver, BC, Canada

What did I learn in Perth III? The whiskey was pretty good and so were a number of scientific presentations. 1) The one keynote I was most interested in was Professor Bradley's presentation on the question: Are high mountains warming faster than other parts of the world. Since observational data in high mountains are scarce he used a range of modelling and paleo type of methods to show that all evidence points in the same positive direction. An elegant way to show the trends using a series of different methods. 2) One of the stated goals of the conference was to promote more interdisciplinary research that includes socio-economics. The talk by Anne Nolin et al. on the Willamette River in Oregon was clearly an outstanding example of a comprehensive watershed based evaluation using an envisioning model to provide decision makers with various science based options. It was one of very few presentations that went beyond documenting the water problems in a scientific way and using community input focused on adaptation options to put science into actions.

John Shaw, USDA Forest Service, Forest Inventory and Analysis, Ogden, UT

Perth III was my first experience with this conference. I had previously participated in an interdisciplinary conference that was focused on a single local mountain range – the Uintas of northern Utah and southern Wyoming – and I count that among the best of conferences I ever attended. As a result, I had high expectations for an international interdisciplinary conference focused on all the world's mountains. Perth III didn't disappoint.

Three things stood out at the conference. First, the issues are as variable as the mountain ranges themselves. What's important



in one mountainous region might be much different than what's important elsewhere. Second, understanding land use history is important to understanding present conditions. This seemed to be a novel idea in many of the presentations, which was somewhat surprising – and especially surprising in places where relatively large populations have occupied mountains for long period of time. Finally, there appears to be a strong desire and need to have globally comparable data on mountain environments. Given the first point, that presents quite a challenge. Most data collection efforts will focus – and rightly so – on the regionally most important issues. However, for many studies (e.g., the ones now focused on land use history) there is commonly an element of “If we were only tracking THIS back then...” Unfortunately, for a given area we don't know what “this” will be in the future. The challenge then appears to be the development of a set of monitoring protocols that can be sustained over long periods of time and are also general enough such that the data they produce can be used to address a wide range of yet-unknown questions. No small task, but given the limitations of retrospective analysis, one worth striving for. The interdisciplinary approach at Perth is a step in the right direction.

Jeremy Littell, Department of Interior, Alaska Climate Science Center, Anchorage, AK

I brought home three messages from Perth. The first, garnered from sessions on treeline, is that treeline research is advancing far faster than would be expected given the meager investment in understanding treeline change. The diversity of mechanisms that interact to cause changes in the treelines of the world is impressive, and as a community, we have moved far, far beyond the 10 degree C isotherm as an organizing concept. But whether we realize it or not, we all now work in a world of “What does it matter?”. Treeline research now needs to focus on putting that observed diversity to use and understanding its causes and changes. The second message was more inferred—that, for better or for worse, “mountain research” writ large is moving on, with or without the physical underpinning required to put its socioeconomic changes into context. Working in Alaska, we are not yet organized around any socioeconomic impacts or social-ecological systems that would make the concept of “mountain observatories” relevant. So it now makes more sense to work on developing what does make sense in Alaska than it does to continue trying to catch up with the concept as defined in other



parts of the world. There is plenty that needs doing here to define what Alaskan mountain science should be, and we know the way forward for the time being. The third, from a conference field trip, which is that coming soon to mountains near you is the antithesis of Joseph Sax's "Mountains Without Handrails" - a funicular to the top of a mountain from which you cannot walk further into the mountains, only look AT the mountains, for too many feet means "losing what we go there for."

Diana Tomback, Department of Integrative Biology, University of Colorado, Denver CO



This conference was an important opportunity for those of us who study mountain forest systems in North America to hear about the dynamic changes taking place in mountain environments in other regions of the world, and to compare and contrast. Our western North American forests, for example, are facing numerous challenges from land use

changes, invasive pests and disease, altered hydrology, more frequent and larger fires, shifting demographics, and native pest outbreaks, driven in large part by warming temperatures. To what extent are these problems afflicting forests elsewhere? Several papers in the session "Linking past land use legacies and future land use trajectories in mountain regions" indicated that forested areas were actually expanding in the Swiss Alps, Polish Carpathians, and Norway from changes in land use, which resulted in abandonment of agricultural lands and the encroachment of woody species. This story is very similar to that of the northeastern United States, where an increase in forested area followed shifts from agriculture to other economies during the nineteenth century. Three papers in the session, "Mountain forests: stresses, disturbances, and ecosystem services," discussed the historical role of windthrow, bark beetle infestations, and fire as natural disturbance factors in European *Picea abies* and *Pinus hedreichii* forests. One paper indicated that these natural disturbances had been intensifying over the last few decades in the Austrian Alps, and an increase in frequency was anticipated in response to climate change. These effects signify that European forests are also experiencing changes in forest structure and composition through multiple disturbance factors. Thus, temperate forests in general appear to be in flux, raising questions about the limits to their resilience and the impact on the ecosystem services that they provide.

Jessica Halofsky, School of Environmental and Forest Sciences, University of Washington, Seattle, WA

At the Mountains of Our Future Earth Conference,

I was struck by all of the different values that people place on and derive from mountain ecosystems.

There were many examples of people depending on mountain ecosystems

for water, grazing, and timber; people valuing

"naturalness" or "letting nature run its course" in

mountain ecosystems; and people valuing a landscape state that was clearly human-caused, but that is enjoyed for its aesthetic value. I was also struck by how pervasive climate change is as a threat to these ecosystem services. But it was also apparent that climate change will have complex effects on mountain ecosystems. We can make broad generalizations about what may happen to treelines, for example, but they may respond differently than we expect. The importance of monitoring in mountain ecosystems was made clear again and again.



Lara Kueppers, Climate and Carbon Sciences Program, Berkeley National Laboratory and Sierra Nevada Research Institute, University of California (Merced), Berkeley, CA

There is a very motivated community of researchers around the globe who are interested in the dynamics of treeline ecotones, and how they're being affected by climate changes. The time is ripe for enhancing communication and coordination of research efforts

to enable projections of change at high elevations, as well as the implications of treeline ecotone change for hydrology, biodiversity and local climate. I also learned that wild blueberries in the Scottish highlands are ripe (and quite tasty) in early October.



Martha Apple, Department of Biological Sciences, Montana Tech, Butte, MT



The Mountains of our Future Earth Conference in Perth, Scotland was a wonderfully enthusiastic, festive and energetic exchange of information and ideas. It was a synergistic multicultural meeting of mountain researchers that will very likely have a positive impact on basic science, conservation,

sustainability and humanity. One important message was on the value of interdisciplinary research in mountain studies. Another was in a question from Greg Greenwood, who asked the delegates, “What will you do next?” which struck me as a call to action, and as a biology professor at a mountain campus, I have

increased the incorporation of mountain studies into my classes. Mountain researchers can by definition be interdisciplinary yet somewhat isolated, so we can use networking, conferences (including their fun social events and field trips), creativity, and our wide range of disciplines to set the stage for collaborations. I was very happy to see the emphasis placed on visual arts, since art is a great way to connect, or articulate, the many divergent and convergent disciplines of mountain research. I left the meeting with the challenge of contributing fine-scaled botanical research to interdisciplinary efforts in our mountain environments but also feeling inspired by the formation of new alliances and by presentations from long-term research programs such as GLORIA. For me, and very likely for others, the messages of the meeting contributed to the formation of new contacts, a strengthening of existing contacts, and a resolve to continue with existing projects and to develop and contribute to new syntheses of ideas and actualities.

Antarctica

Andrew Fountain

*Departments of Geology and Geography
Portland State University, Portland, Oregon*

I conduct my research in Antarctica, the McMurdo Dry Valleys of Antarctica, to be precise (Fig. 1). It is the largest ice-free region on the continent and spans about 5000 km². My research falls under the umbrella of the Long Term Ecological Research project (LTER), an NSF-funded program. The LTER maintains 25 sites of which two are in Antarctica (we're one of those two), one in the Pacific, one in Puerto Rico, and the rest on mainland USA. Our site is microbially-dominated with no higher plants or animals. Ours may be the southernmost terrestrial ecosystem; it is composed of soils, ice-covered lakes, and streams that flow for a few weeks each summer. My part of the project is glacier hydrology. Specifically, I define the physical controls and processes of meltwater flow from the glaciers that drive the microbial ecosystem on the valley floor.

I don't ever really want to go to Antarctica. It is a long way away, and a long time from family and friends. I suppose my 20+ hour

total flight time is better than going the other way, a 3-day voyage across the Southern Ocean from South America. I'm not much for planes but even less for the open ocean. The National Science Foundation limits American access to Antarctica to two routes: by boat from South America to the Palmer Peninsula and Palmer Station; or by air from Christchurch, New Zealand to McMurdo Station on the other side of the continent. Most of us go by air to McMurdo because that station is the gateway to the 'deep field' of Antarctica including South Pole Station. Palmer Station, by contrast, is a small facility with only local access by boat.

The flight from the US to New Zealand is just a long flight, 12+ hours, made longer recently by routing through Sidney, Australia with a nice long layover. Once in Christchurch, we check in and attend clothing issue. You don't really have to bring your own field clothes other than underwear because NSF supplies everything. The NSF Antarctic Program doesn't want to get

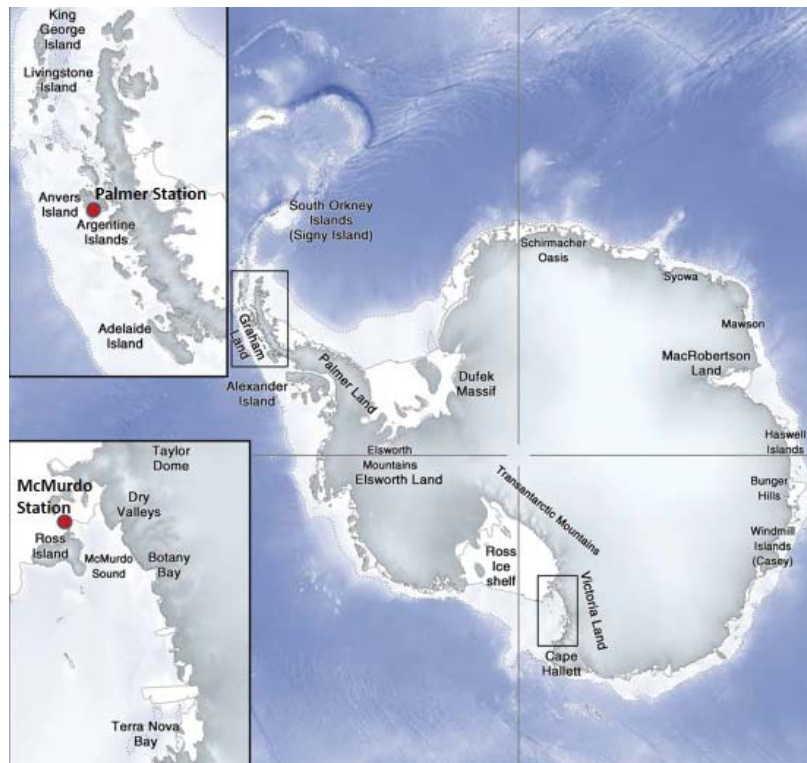


Figure 1. Location map. Courtesy of Peter Convey, British Antarctic Survey.

involved in the business of evaluating clothes you brought and making you buy new ones if yours are found wanting, so they simply provide cold weather gear: boots, pants, gloves, hat, coats, everything. And we are required to take the gear and wear it on the flight down and back. It provides critical survival capability. In practice, we all take our own stuff and use the issued clothing when required or convenient.

The nice thing about the Southern Hemisphere in general and New Zealand in particular is that when we arrive it's spring or summer. The Antarctic field season for those traveling through McMurdo is October through January. Before or after means limited light and increasingly cold temperatures. On arrival in New Zealand we're greeted by a warm sunny climate, almost vacation-like if the departure for Antarctica were not a day away. Delays are common due to weather in Antarctica or mechanical issues with the aircraft, and the delays may last from one to several days. On my first trip down, years ago, I was delayed 5 days. The good thing is that it's nice to relax in New Zealand and soak up the summer. The bad thing, of course, is that delays also delay the field season, and depending on timing may even shorten the field season. Before the earthquake of 2010, Christchurch was a fabulous place to stay and on the way home a great place to take a day or so of R & R. After the earthquake, much of the downtown and many of our cherished restaurants, hotels, and B & Bs are gone. The downtown area is populated by grass-infested vacant blocks; it looks like a city of abandoned parking lots.

The flight from Christchurch to McMurdo is always hot and exciting. Hot because we have to wear all the cold weather gear issued to us. Standing in line on a summer morning in Christchurch can be hot even without the coats that keep you warm at -40F. It's exciting because we fly military air command, which means the stripped-down shell of an aircraft. If it's a ski equipped C-130, then we sit in jump seats meant for paratroopers and we get an 8+ hour ride. In good years we'll get a C-17, a much bigger aircraft with 'normal' seats and only a 5-hour ride. In either case the aircraft is so loud that ear plugs are issued (and worn), minimizing conversation. In fact, hand signals must be used to request passage to the bathroom (an opaque shower curtain around a urinal for the men).

The runway in Antarctica is snow-covered ice. Exiting the dark interior of the aircraft one faces the blinding white light of the runway, a sharp and momentarily painful contrast to the dark cabin (Fig. 2). Even with sunglasses eyes take a bit to adjust. As you stumble out of the aircraft from sitting for 5+ hours, wearing incredibly large white rubber ("mickey mouse") boots, you find yourself surrounded by miles of flat white with mountains in the distant background, and a few ski-equipped portable buildings and vehicles in the foreground. The cold air of Antarctica bites your face. When I survey the scene around me, my reluctance about the travel disappears and I don't really want to be anywhere else. This is where I want to be. My momentary introspection is interrupted by people greeting their work-mates who have just



Figure 2. The LC-130 has just landed and I'm off the aircraft ... finally. The flight was nine hours and it's good to stretch my legs. A couple of support buildings are in the distance.

arrived. You're not one of them. They're the seasonal employees who provide logistical support; me, I'm a temporary visitor, a scientist in to do my thing and then leave. I'm a short-timer of a month or two in the field, not a station resident of 4 months.

McMurdo Station, aka 'town', houses somewhere between 800 and 1000 people, most of whom provide logistical support for the scientists. A fraction are transients, like myself, who stay a few days to a week before going to the field. Town is like a university campus, with the look of an Alaskan village but with a utopian feel. We all stay in dorms and most of us have room mates. We eat in a nice cafeteria (the 'galley'), have movie nights, local bands, and so on. There are a couple of bars as well. Unlike a university campus it has no grass, just a dusty volcanic island with telephone poles and above-ground pipes, and big trucks often rumble through. Everybody has a job, and everybody has worked pretty hard to get there so the mood is friendly, helpful, and positive. My main job in town is to get ready to go to the field. That may include arranging the logistics of helicopter travel, drawing food, and unpacking/packing equipment boxes. After a waste management class (90% recycling), a field safety class, and a helicopter safety class, I'm ready to deploy to the field. If I used a snow mobile, worked on sea ice, or drove a truck, there would be more safety classes.

The field area is composed of sandy gravelly valleys with perennially ice-covered lakes and ephemeral streams draining from alpine glaciers that descend into the valley bottoms. Think Death Valley with glaciers (Fig. 3). The ice sheet is blocked by the Transantarctic Mountains and the 'rain shadow' from the mountains greatly reduces the snowfall. Being a polar desert it doesn't really snow that often, a few times a season at most. And because it is dry and cold the snow commonly sublimates (solid to gas) before melting significantly so the only source of melt water in the summer is from glacial melt. Air temperatures are commonly a few degrees below freezing and for short periods, hours to days, it can warm to a few degrees above freezing. Typically it's colder in Chicago than where we are. As my deep-field friends like to remind me, I work in the banana belt of Antarctica.

The silence of the valleys envelops you, but wind may pick up, giving the air its sound. The color of the landscape is simple and elemental. The valley floor is a reddish-brown with occasional splotches of black from volcanic deposits. The glaciers are a white-grey and the sky is blue. That's it. The sun is continuously at a low angle creating sharp shadows and contrasts, making us all expert photographers. The landscape is dramatic with the valley walls rising to 6,000 feet at angles of 30 or 45 degrees.



Figure 3. We get to motor over the lake ice. This is spring and the ice is smooth and solid. Suess Glacier in the background and the Asgard Range rises to 2000m outside of the photograph.

And winds sweep down off the plateau (where the ice sheet is), 10 miles away, and funnel through the valleys with speeds reaching 50 mph or more, blowing snow, sand, and poorly strapped-down tents, and whatever else, all around.

We work out of a camp composed of a house-trailer-like building where we eat, relax, and work on computers. We have a couple of out-buildings, about 8'x10' square. Each is devoted to a different use: a biology lab, a chemical lab, and a building for field instrumentation. We sleep in tents and the camping is quite nice. The tents are on the sandy gravelly valley floor with about 10-40 cm of unconsolidated gravelly sand before we would hit ice-cemented permafrost (Fig. 4). With air temperatures just below freezing the tent is quite warm in the sunlight, which shines 24 hours a day during the field season. Tent temperatures can be about 40° F. Nice. Of course when the skies are overcast you know you're in Antarctica. On sunny days, time is defined by where the sun is hitting the tent, but on cloudy days you have no clue. I've woken in the middle of the 'night' panicked because I thought I missed the departure time. Checking my watch revealed it was only 3am. Some folks have problems sleeping in the daylight. They wear eye masks or pull a wool hat over their eyes. For me it's a great nap, every day.

Not all folks in the field take showers. I do, and it's a luxury, once a week whether I need it or not. I use a little better than a gallon of water heated by a kerosene stove in a small hut that is so hot it's like a sauna. I pour the water over myself dripping into a

drain pan in which I'm standing. Some soap, another pour. Wash the hair, another couple of pours. Heaven. The water is conveyed from the drain pan into a bucket that is emptied into a 55 gallon drum, which eventually gets shipped out of Antarctica back to Los Angeles. The same goes for dish water. The same with urine. We have pee bottles, one liter Nalgene bottles, that get filled during the day (by men AND women) and emptied each evening or morning into a 'u-barrel'. That too gets flown out. Because of the sensitive and pristine nature of the environment, our footprint is kept as small as possible. Thinking of pee bottles, there is no team building exercise better than when your field partner asks for your bottle because he forgot his. It gets better – when he hands it back with thanks. Well, somebody has to carry it.

Our work on the glaciers is by foot. We don't use a snowmobile and where the ground is snow covered we commonly use snowshoes because the wind-blown snow is hard, and conditions so variable it makes skiing more frustrating than enjoyable. Because of snow-covered crevasses we're commonly roped together, making skiing a further challenge. We may be dropped off by helicopter to do our work for the day. The second-best sound of the day is when the helicopter leaves and we are enveloped in the silence of the valleys. (best sound is when, after a long day, it returns to take you to camp, warmth, and food). Our work takes us across a variety of glaciers, each quite different from others. Because the ice is quite cold at depth (~ -20° C) melt water created on the icy surface (no melting of the snow surface) enters a crevasse, freezes, suturing the crack and making large expanses of ice very safe for walking. And the melt-freeze of the ice surface can create surfaces so smooth that we should be wearing ice skates. Thank goodness for crampons. On other glaciers narrow melt channels develop, forming slot canyons maybe 10 or 20 m deep. We have a favorite called 'Hollywood Channel' because it's narrow, winding, and overhung with long icicles (Fig. 5). Because of the melt and freezing every year it changes dramatically making it new and different every visit. It is an icy labyrinth of blue-white ice of the kind imagined only in fantasy stories.

For me, I quickly adapt to the environment of the Dry Valleys and camp life, and I don't need to be anywhere else. I've been doing this for twenty years and it never gets dull. Sure, I miss my family and friends, but otherwise I'm content to be there, dragging chunks of ice that have fallen from the face of the local glacier back to camp for drinking water. Having dinner around a table with a group of people who also savor this experience. The season has to close and we've done what we've come down to do. Returning to "town" is never a joyful event except for the distant feeling that this is one step closer to home.



Figure 4. Lake Hoare Camp. While most camps have 5 gallon plastic buckets for a bathroom we have that and these two outhouses that burn the contents. A small lab is in the middle background, and the hut is the long building. Note the tent behind that. Canada Glacier flows down from the left and Howard Glacier is across the valley. You can tell its mid-summer, the pond has melted out.



Figure 5. One of the fun channels to explore on Taylor Glacier. This one is wide open compared to Hollywood Channel.

This section of *Mountain Views* spotlights regions where we—mountain scientists, resource managers, and other professionals—work. Feel free to submit Field Notes about your favorite mountain area. —Editor



View west from South Tufa of Mono Lake, CA. Photo: Benjamin Hatchett.

A View from South Tufa, Mono Lake, California

Benjamin Hatchett

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At the foot of the steep eastern escarpment of the ~3800 m high Sierra Nevada lies Mono Lake (38°N, 119°W), one of western North America's most unique and productive ecosystems (National Resources Council 1987). At least 760,000 years old, Mono Lake is one of the oldest lakes in North America and for the past 140,000 years it has been a terminal lake (a lake with no outlet to the sea). Between the lake and mountain crest there exist 14 ecological zones in which more than 1000 plant species and 400 vertebrate species have been documented (Winkler 1977). Mono Lake and other Great Basin terminal lakes provide important stops along the Pacific Flyway—stretching from Alaska to Patagonia—for migratory birds including Eared Grebes (*Podiceps nigricollis*) and Wilson's Phalaropes (*Phalaropus tricolor*). Phytoplanktonic and benthic algae (*Nitzschia communi* and *N. frustulum*), brine shrimp (*Artemia monica*), and flies (*Ephydra hyans*) occupy its alkaline waters and form the base of the food chain. Yellow warblers (*Dendroica petechia*) and hairy woodpeckers (*Leuconotopicus villosus*) flourish in the riparian corridors while terrestrial wildlife such as Bighorn Sheep (*Ovis*

canadensis) and American pika (*Ochotona princeps*) inhabit the montane zones. Two large volcanic islands, Paoha and Negit, are favored nesting regions for California gulls (*Larus californica*). Tufa deposits, which form via biogenic and inorganic calcium carbonate precipitation, provide nesting locations for Osprey (*Pandion haliaetus*) and homes for the alkali flies. Mono Lake's unique aqueous environment has also provided insight into geobiology via the discovery of a bacterium (GFAJ-1; Wolfe-Simon et al. 2010) capable of metabolizing phosphorus in the presence of exceedingly high (~4,000 fold) arsenate concentrations (Elias et al. 2012).

Mono Lake offers an ideal natural laboratory to investigate the impacts of climate change, which operates over a broad range of timescales from subdecadal (less than 10 years) to millennial (1000s of years). Because it has no outlet to the sea, Mono Lake's surface area expands and contracts as the climatic supply and demand for water vary with time. Israel Russell first described how the responses of Mono Lake to past climate

variability are recorded by geomorphological indicators such as wave-eroded shorelines and glacial moraines (Russell 1889). Living and submerged forests provide centennial (100s of years) through millennial (1000s of years) records of fires (Millar and Woolfenden 1999) and climate (Stine 1994). Lake and meadow cores also yield various ecological proxies (Davis 1999). These data provide important clues about the timing, duration, and magnitude of past fluctuations in water availability. Through integrated studies involving numerical modeling, field, and laboratory efforts, examinations of how terminal lakes have responded to past hydroclimate change during prolonged wet and dry episodes yield understandings of how dryland water resources might change under scenarios of present and future climatic change (Broecker and Putnam 2013, Hatchett et al. 2015). Linking past physical changes to reconstructions of vegetation responses, such as treeline and community composition, will help estimate the sensitivities of biological communities to future climates (e.g., Malanson et al. 2007). Monitoring the impacts of present-day climate change on the physical characteristics of the Mono Lake Basin, such as lake chemistry and ecosystem thermal regimes, provides insights into how various elements of biodiversity respond to environmental change operating on local, regional, and global scales.

In the early 1900s, William Mulholland built the 375 km long Los Angeles Aqueduct to transport water from the Owens Valley (the next valley south of Mono Lake) to the burgeoning city of Los Angeles. As the city and its thirst grew during the post-WWI era, the gravity-fed aqueduct was extended 220 km northward into the Mono Basin where it diverted water out of the Sierra Nevadan streams feeding the lake. These diversions began in 1941 and over the next 40 years the lake surface elevation fell nearly 15 m. The reduction of inflow caused salinity to increase while algae and brine shrimp populations decreased. The nesting grounds on the islands favored by gulls became vulnerable to predation. Air quality declined as the characteristically strong winds of the Eastern Sierra mobilized alkali dust. In 1983, a case of *National Audobon Society v. Superior Court* was brought to the California Supreme Court by a group of environmental activists who later formed the Mono Lake Committee. For years, the group had documented the ecological degradation of the lake. After the initial victory of *National Audobon Society v. Superior Court*, the ruling was finally enforced by California State Water Resource Control Board Decision 1631 in 1994. These legal victories incorporated integrated ecosystem science (Winkler 1977) and represented the revival of the public trust doctrine in the western United States. Decision 1631 mandated a lake level of 1948 m and struck a balance between protecting the ecology of the lake in the interest of the public trust while still

providing water for urban use. Had a cooperative agreement not been reached, the Mono Lake visible in the photo today, which provides a recreational and ecological haven, would be very different indeed.

Mono Lake symbolizes one form of the human-environment nexus in the arid western United States. Although Decision 1631 allowed the lake to persist, contemporary regional climate change is affecting the Mono Basin in several ways. Increased air temperatures are warming the lake and altering the biogeochemical balance as well as reducing the fraction of precipitation falling as snow, thereby changing the timing and magnitude of runoff into the lake. Rates of evaporation from the lake surface and watershed evapotranspiration also rise with temperature, placing greater strains on the Basin's limited water resources. The continued diversion for urban usage reduces total inflow into the lake, further exacerbating climatic water deficits. As the lake becomes increasingly meromictic, vast changes in the ecosystem will occur. Continued efforts working towards preservation and further ecological restoration of Mono Lake by stakeholders, policymakers, and scientists will be necessary to increase the likelihood of this highly diverse and important ecosystem of western North America to remain viable under a climatically-uncertain future. By implementing adaptation and technological measures designed to improve conservation and water use efficiency in cities such as Los Angeles, thereby reducing or eliminating the need to transport water out of the Mono Basin, the socioeconomic and ecologic resiliency to future climate variability and change in both places can be improved.

In conclusion, Mono Lake presents not just a world-class field research location, but offers an excellent learning environment for both students and the public. It provides easily accessible venues to explore the important components of diverse ecosystems. The steep gradients of climate zones, from alpine tundra on the mountain crest to the alkaline lake basin yield diverse ecosystems waiting to be explored and discovered. Examples of restoration efforts abound, with many more projects waiting to be implemented. Many lifetimes' worth of scientific research awaits bright minds and better questions. While the exact outcome of Mono Lake is uncertain in the face of today's challenges, its natural beauty and complex environment will no doubt continue to inspire scientists and naturalists alike for generations to come.

Acknowledgements

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"Troubled Waters (Mono Lake)", Watercolor – 22" x 30" by Valerie Cohen.

Did You See (Hear, Touch, Smell, Feel) It?

This section of Mountain Views relates sense-based encounters with mountain weather, climate, and environments. Past contributions have described unusual visual phenomena, such as cloud or ice formations. Thanks to Margaret Eissler for her essay, which highlights our auditory senses and reminds us that music—of the flute, wind, or birdsong—is an important medium for learning. —Editor

Yosemite Music Walk

Margaret Eissler

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El Portal, California*

Some say that Pan, the Greek god of the forests and meadows, made the first flute. Half man, half goat, he fell in love with a nymph named Syrinx. As he pursued her, she called out to the other nymphs for help. They changed her into a bed of reeds. As Pan sighed in disappointment, his breath passed over the reeds, making beautiful, haunting, many pitched sounds. On an impulse, Pan cut a few reeds into different lengths, tied them together, and blew across the edges. These reeds tied together are called panpipes or Syrinx for the nymph hidden inside. “Syrinx” is also the name for the voice box or vocal organ of birds. Not surprisingly, flutes are considered the birds of the orchestra.

Flutes are ancient instruments and undoubtedly one of the first. Cultures around the world separately came up with their own, making them out of bird bones, reeds, bamboo, hollowed out elderberry branches, pipes or tubes made of clay, wood, and now plastic and metal. Air blown across an edge defines a flute.

Before becoming a ranger naturalist in Tuolumne Meadows, I freelanced as a musician. I taught flute lessons, played with the Santa Barbara Symphony and other orchestras, and picked up music jobs I could find. My degrees were in studio art and music performance, not the more usual scientific background my future ranger colleagues had. Fortunately, my childhood connection and long history with Tuolumne Meadows filled the gap.

When I first came to work in Tuolumne Meadows in 1985, ranger naturalist Paul Tidwell had been leading a popular weekly sunset music walk that gradually moved up the apron of Lembert Dome for greater and greater views. He had the gift of a silver tongue—so articulate and thoughtful. Since his music had come from a portable system, my flute playing took its place. I hid in the forest and, on cue, played birdsongs and short pieces we had chosen to complement his words.



Margaret plays flute to the Tuolumne sunset.

One week that first summer, Paul had to be away. That meant I had to come up with my own version of a music walk. I focused on the mysterious, transformative power of music—how does it transport and touch us so deeply?—and flutes, how they work, their history, birdsong, how the flute is a woods instrument. Early in the program, I played *Syrinx* for unaccompanied flute by Debussy. In my mind, it is Pan's attempt to call the nymph out of the reeds.

Since then I have created two additional sunset music programs: one about the views and perspectives we gain from being up high—peaks, domes, and outer space. The group reads to each other a sequence of quotes by astronauts, their words eloquent

about our home planet. Between readings, I play songs and dances from around the world. The second program is about listening—really listening—and breathing, music and poetry. Members of the group read selected poems out loud. The programs, performance art pieces really, change each week with the weather and light of the early evening and the diverse voices, young and old, often with accents from other parts of the world.

Playing flute outside—in the woods, on the dome—directing air across an edge, competing with the wind, sending birdsong into the air in concert with other birdsongs, the sunset and sometimes the moonrise, many voices, beautiful words, inspiring thoughts, rapt children—what more?



Margaret plays for a Yosemite Music Walk on Lembert Dome.

American Geophysical Union (AGU) 2015 Fall meeting in San Francisco

CIRMOUNT is sponsoring a session at the 2105 Fall Meeting of the American Geophysical Union in San Francisco, California (week of Dec 14-18), Moscone Center.

Session Title: Climate Refugia in a Changing World: Climatic and Hydrologic Processes Informing Ecological Responses.

C13J. ORAL: Climate Refugia in a Changing World: Climatic and Hydrologic Processes Informing Ecological Responses, Monday, 14 December 2015; 13:40 - 15:40; 3005 Moscone West. Invited Presenters: Mike Dettinger (USGS), Solomon Dobrowski (Univ Montana), Joe Ebersole (EPA), and Toni Lyn Morelli (DOI, NE CSC)

GC11C. POSTERS: Climate Refugia in a Changing World: Climatic and Hydrologic Processes Informing Ecological Responses, Monday, 14 December 2015; 08:00 - 12:20; Moscone South, Poster Hall

Conveners: Connie Millar (USFS), Toni Lyn Morelli (DOI, NE CSC)

As is now tradition, there will also be an informal dinner for CIRMOUNT colleagues and friends on Monday night, 14 December, in SF near Moscone Center.

Write Connie Millar, cmillar@f.fed.us, if you are interested.



Golden Gate Bridge, San Francisco.

MtnClim 2016

The Biennial Conference of CIRMOUNT

MtnClim 2016: Mountains Without Snow, What Are The Consequences?

Sleeping Lady Resort in Leavenworth, Washington, October 17-21, 2016

The 2016 Mountain Climate Conference (*MtnClim 2016*) continues the decade-long tradition of serious interdisciplinary mountain science in an informal mountain context. *MtnClim 2016* will include oral and poster presentations featuring keynote lectures by thought leaders in the field as well as highlighting exceptional early-career scientists, providing forums for resource managers, and integrating undergraduate and graduate students.

MtnClim 2016 will explore the central theme of “Mountains without snow; What are the consequences?” in addition to sessions on other current science themes, climate policy, and decision-support. *MtnClim 2016* will highlight the role that mountain snowpack plays in irrigation, hydroelectric generating capacity, and salmonid populations. The 2016 conference will contain three additional foci on the central theme of understanding the role of potentially declining snowpack in mountainous social-ecological systems:

- 1) Explore the impacts of the 2015 drought on ecosystem services in the American West;
- 2) Understand the implications of rain-on-snow events for hydroelectric power generation in the Cascades;
- 3) Discuss how we can manage snowpack for food, energy, and salmon in the Pacific Northwest and beyond.

Information about registration, lodging, and the program will be added to the following website as it becomes available: <http://www.fs.fed.us/psw/cirmount/meetings/mtnclim.shtml>.

Contact Andy Bunn, Andy.Bunn@wwu.edu, for information.



Sleeping Lady Resort in Leavenworth, Washington.

PACLIM Workshop: March 5-8, 2017

CIRMOUNT modeled its flagship MtnClim conferences after the decades-long model of PACLIM. PACLIM (Pacific Climate) is a multidisciplinary workshop that broadly addresses the climatic phenomena occurring in the eastern Pacific Ocean and western North America. The purpose of the workshop is to understand climate effects in the region by bringing together specialists from diverse fields including physical, social, and biological sciences. Time scales from weather to the Quaternary are addressed in oral and poster presentations. Workshops convene at the Asilomar State Conference Center, Pacific Grove, California.

Write Michelle Goman, goman@sonoma.edu, or Scott Mensing, smensing@unr.edu, for information.



Pacific coast near Asilomar.

Mountains 2016

Conference website: <http://cimo.esa.ipb.pt/mountains2016/>



Mountains 2016 is an international event aiming to promote sustainable development in mountains, based on science, knowledge, and innovation.

Mountains 2016 will combine two different events: the X European Mountain Convention and the I International Conference on Research for Sustainable Development in Mountain Regions.

The **X European Mountain Convention** continues a 20-year tradition of addressing cutting-edge political, economic and social topics in European mountains by **Euromontana**, the European Association for the Development of Mountain Areas. It will cover a broad range of subjects, from agriculture to energy and from innovation to governance, this year centered around the topic of “Adaptation to climate change”.

The **I International Conference on Research for Sustainable Development in Mountain Regions** is a scientific meeting aiming to share and discuss methods, tools, results, applications, trends and challenges in research in mountain systems. It will be organized for the first time in Bragança, under the theme “Ecosystem services and sustainable development”.

By bringing together the European mountain community and a broader international community of scientists and stakeholders, *Mountains 2016* will create a unique opportunity for individuals and institutions to share experiences and to establish information and collaboration networks. By jointly addressing climate change adaptation and ecosystem services in mountain regions, it will provide an exceptional occasion to present important contributions to science and sustainable development in the mountains of Europe and the rest of the world.

Mountains 2016 is a collaboration organized by the Mountain Research Centre (CIMO) of the Polytechnic Institute of Bragança (IPB), in Portugal, with the active involvement of local, national and international institutions. The event relies in part on a connection between Portugal and Brazil, established between CIMO/IPB and Embrapa, which gives the initiative a particular Lusosphere context. One goal of the conference is to involve the global Portuguese-speaking community to the greatest extent possible.

X European Mountain Convention

3-5 October 2016

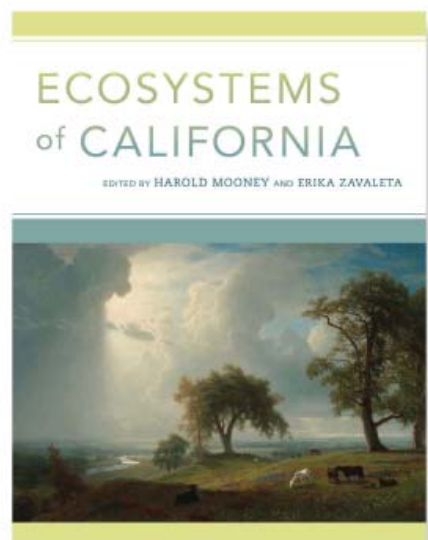
The European Mountain Convention is organised every two years by Euromontana, the European Association for the Development of Mountain Areas, in different parts of Europe in collaboration with one of their 75 members. In 2016, it will be organised with IPB-CIMO in Bragança – Portugal from the 3rd to the 5th October 2016 and it will focus on “climate change in mountain areas”.

I International Conference on Research for Sustainable Development in Mountain Regions

5-7 October 2016

The I International Conference on Sustainable Development in Mountain Environments (ICSDME) aims to share knowledge on mountain systems – agricultural, semi-natural, and natural – concerning research methods, tools, results, applications, and trends and challenges. Another key goal will be to link research in mountain areas in several regions of the world, with an emphasis on Europe and South America and Portuguese-speaking countries.

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Ecosystems of California

EDITED BY HAROLD MOONEY AND ERIKA ZAVALETA

This long-anticipated reference and sourcebook for California's remarkable ecological abundance provides an integrated assessment of each major ecosystem type—its distribution, structure, function, and management. A comprehensive synthesis of our knowledge about this biologically diverse state, *Ecosystems of California* covers the state's oceans to mountaintops using multiple lenses: past and present, flora and fauna, aquatic and terrestrial, natural and managed.

Each chapter evaluates natural processes for a specific ecosystem, describes drivers of change, and discusses how that ecosystem may be altered in the future. This book also explores the drivers of California's ecological patterns and the history of the state's various ecosystems, outlining how the challenges of climate change and invasive species and opportunities for regulation and stewardship could potentially affect the state's ecosystems. The text explicitly incorporates both human impacts and conservation and restoration efforts and shows how ecosystems support human well-being. Edited by two esteemed ecosystem ecologists and with overviews by leading experts on each ecosystem, this definitive work will be indispensable for natural resource management and conservation professionals as well as for undergraduate or graduate students of California's environment and curious naturalists.

Harold Mooney is Professor of Environmental Biology at Stanford University and a member of the National Academy of Sciences. He has authored over 400 scientific articles and is coeditor of *Methods in Ecosystem Science* (Springer, 2013) and *Invasive Species in a Changing World* (Island, 2000), among other books.

Erika Zavaleta is Professor of Environmental Studies at University of California, Santa Cruz. Her research bridges ecological theory with conservation and management practice. She received the 2008 Sustainability Science Award from the Ecological Society of America and has published in *Science*, *Nature*, and the *Proceedings of the National Academy of Sciences*.

968 pp. 8 1/2 x 11

Illustrations: 14 maps, 142 b/w images, 53 tables, 258 color images

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A WAY ACROSS THE MOUNTAIN

Joseph Walker's 1833 Trans-Sierran Passage and the Myth of Yosemite's Discovery

By Scott Stine



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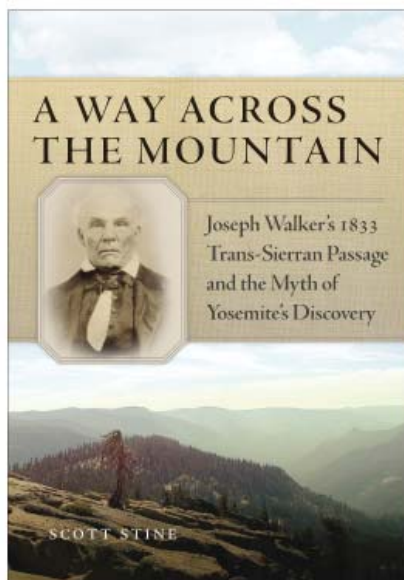
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320 PAGES, 7 X 10

33 B&W ILLUS., 19 MAPS, 1 CHART

U.S. HISTORY



A painstaking reconstruction of a legendary expedition—and what it really discovered

From July to November 1833, Joseph R. Walker led a brigade of fifty-eight fur trappers, with two hundred horses and a year's provisions, from the Rocky Mountains of Wyoming to the Pacific coast of central California. Toward the end of their journey the Walker brigade crossed the Sierra Nevada, becoming the first non-Native people to traverse the range from east to west. That crossing, made long and brutal by bewildering terrain and deep snow, is widely and rightly considered a milestone in the exploration of intermontane North America.

Following Walker's death in 1876, an alluring tale arose concerning his trans-Sierran route. In the course of the crossing, goes the story, Walker found himself on the northern rim of Yosemite Valley at the plungepoint of North America's tallest waterfall, staring into the most awesome mountain chasm on the continent. Over the decades since then, this time-honored tale has hardened to folklore. Dozens of historical works have construed it as a towering moment in the opening of the West.

But in fact this tale of Yosemite's discovery has no basis or support in firsthand accounts of the 1833 Sierran crossing. Moreover, there is much in those accounts that contradicts Yosemite

lore, and much that points to a trans-Sierran route well north of Yosemite Valley.

In *A Way Across the Mountain*, Scott Stine reconstructs Walker's 1833 route over the Sierra. Stine draws on his own intimate knowledge of the geomorphology, hydrography, biogeography, and climate of the Sierra Nevada and Great Basin, and employs the detailed travel narrative of the Walker brigade's field clerk, Zenas Leonard. Stine documents the inception, growth, and persistence of the Yosemite Myth and explores the extent to which that lore has overshadowed Walker's greatest discovery—that the huge swath of continent between the Wasatch Front and the Sierran crest is hydrographically closed, draining not to an ocean, but to salty lakes and desert sands.

Scott Stine is Professor Emeritus in the Department of Anthropology, Geography, and Environmental Studies at California State University, East Bay. He resides in Point Reyes Station, California.

This issue of *Mountain Views* continues our tradition to highlight artistic work of contributing authors and other mountain-science colleagues.

Amy Holden (Woolvin) is a research assistant with the Centre for Mountain Studies, University of the Highlands and Islands of Perth College, Perth Scotland, and was instrumental as logistics coordinator for the Perth III *Mountains of our Future Earth Conference*. She is also an accomplished artist. Her PhD thesis, “Landscape values, management and art in Highland Scotland: Can cultural values be incorporated into landscape management practices”, speaks to Amy’s interdisciplinary blend of interests in science, management, and art. Amy’s painting of the Scottish Highlands was used as the cover illustration on the program for the Perth III *Mountains of our Future Earth Conference*. Amy was generous to allow us also to use that painting, “Snow on Canisp and Suilven, Lochinver“, for the front cover of *Mountain Views*, and other of her paintings in this issue. In Amy’s words:

In my work—both academic and painting—I wish to explore the multiple and varied relationships between people and landscapes. I am fascinated by the constantly changing nature of landscapes, the complexity of processes within them—the weather, geology, landforms, ecology and culture (both past and present)—and the interactions between these processes. When I paint I wish to capture these ephemeral qualities and so create flow within the paintings. How we experience landscapes and the memories we create within them are what I aim to convey within my paintings. Painting for me, is a way of articulating and expressing my own experiences within landscapes and through the use of colour and texture create feeling and emotion within the paintings.

Find more of Amy’s paintings at:
www.adventureswithlandscapes.co.uk

Hassan Basagic has been monitoring, assessing, and photographing glaciers of western North America for more than a decade, having completed graduate work in the Department of Geology at Portland State University (PSU), Oregon. For seven years, Hassan served as field team leader in Antarctica for glacier research conducted by Andrew Fountain. Hassan maintains a research affiliation at PSU, and presently is watershed GIS specialist with the Portland Water Bureau.

Martha Apple is Professor in the Department of Biological Sciences, Montana Tech, Butte, Montana. Her mountain-related research focuses on responses of alpine plants to climate change, with special interest in the role of plant functional traits. Martha manages a GLORIA Target Region (Global Observation Research Initiative in Alpine Environments) in Montana, and is active in the international GLORIA research community. Her painting of Mt. Hood that we include was rendered from a view near Timberline Lodge.

Valerie Cohen has contributed mountain paintings to previous issues of *Mountain Views*. We include one of her paintings of Mono Lake to accompany the Field Notes in this issue. Valerie is a landscape and botanical artist, lives in the Sierra Nevada, and visits Mono Lake often. See more of Valerie’s work at <http://valeriepcohen.com/>

Larry Ruth has written poetry as long as he has pursued environmental work. Currently Larry is Principal and Chief Research Analyst for Lawrence Ruth and Associates, and served previously as academic coordinator and environmental policy analyst for the College of Natural Resources, University of California, Berkeley. Larry has hiked the high Sierra Nevada, California, for many decades, where he finds inspiration for much of his poetry.

Neither science nor the arts can be complete without combining their separate strengths.
Science needs the intuition and metaphorical power of the arts, and the arts need the fresh
blood of science.

—Edward. O. Wilson, from "Consilience, The Unity of Knowledge"

South Fork, Kings River

Old juniper, old artificer, blue berries,
gin and July, you've done this walk
once, twice, or a thousand times, now
walk out of the valley, on the granite
out of yourself, not one apart
from granite and gruss,
from the sound and flow,
stop at the tall pine, *jefferyii*,
smell of the bark vanilla,
think about pie crusts, what else?
Cookies my mom used to make,
blue blazes, sunlight downstream,
stanzas of delphinium, towering
larkspur, little dolphins
leaping from the stem.

—Larry Ruth, July 2015



Half Dome, Yosemite National Park. © Amy Holden (Woolvin).



Old Man of Storr from Applecross Peninsula [Scotland]. © Amy Holden (Woolvin).