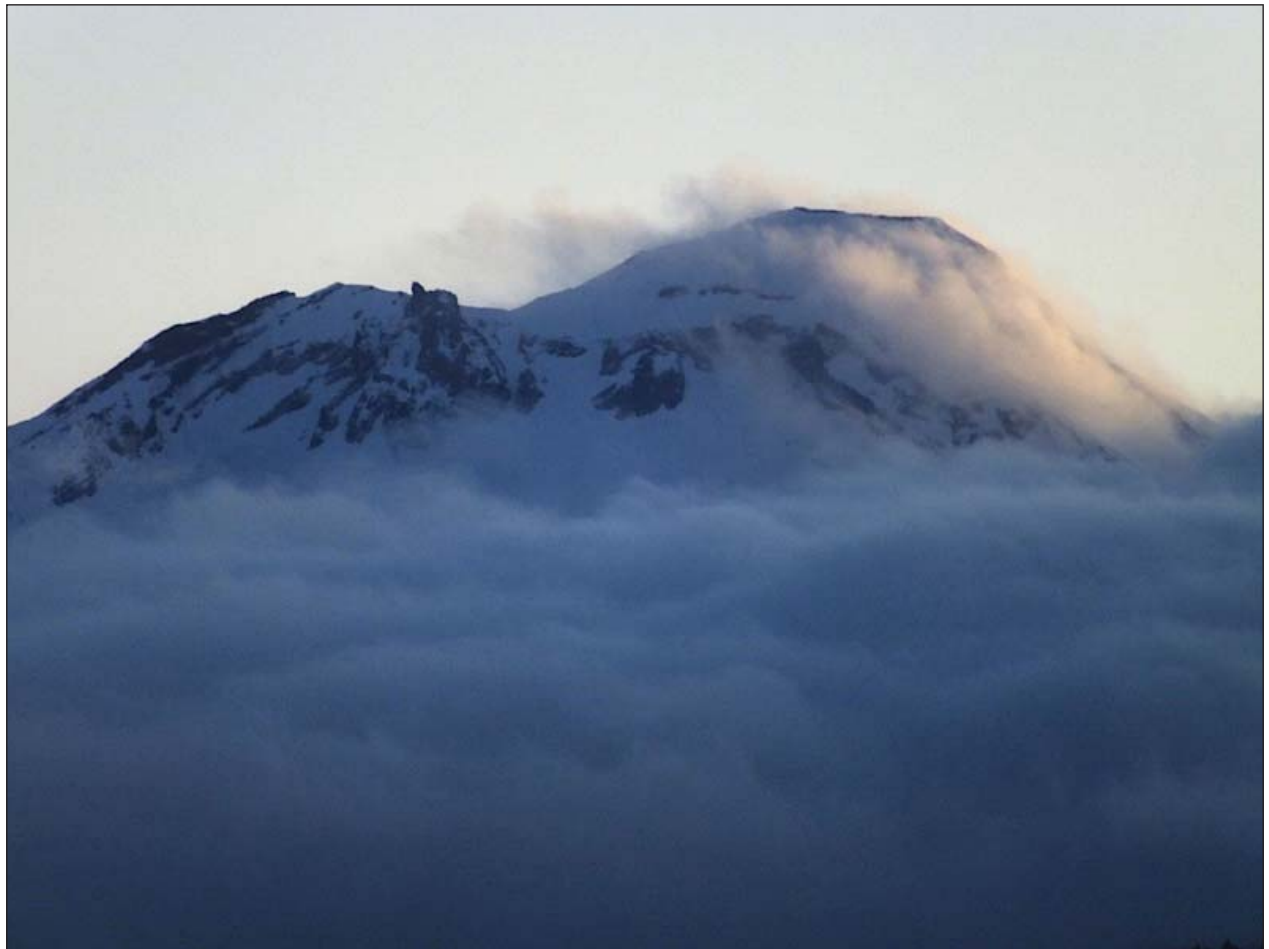


MOUNTAIN VIEWS

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



Informing the Mountain Research Community

VOL. 7, NO. 2
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En route Reno to San Diego looking into Mexico. Photo: K. Redmond

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Front Cover: South Sister, Oregon Cascades. Photo: J. Blanchard

Back Cover: South Sister from Broken Top, Oregon Cascades. Photo: J. Blanchard

Read about the contributing artists on page 52.

Mountain Views

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

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Volume 7, No 2, November 2013

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

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Clouds SE Wyoming. Photo: J. Hicke

The Mountain Views Newsletter

Welcome to *Mountain Views*, the biannual newsletter of the Consortium for Integrated Climate Research in Western Mountains (CIRMOUNT, www.fs.fed.us/psw/cirmount/). Gathered in these pages are reports on current mountain-climate and climate-response studies, *Brevia* of recently published articles, book reviews, mountain climate news and announcements, and our seasonal round-up of mountain artwork, with focus this issue on mountain clouds.

Two events sponsored by CIRMOUNT are upcoming, and I hope you can attend one or both. At the annual Fall meeting of the American Geophysical Union (AGU) in San Francisco, California, CIRMOUNT convenes sessions on “Climate Change and Wildfire: Drivers, Interactions and Consequences”, organized by Don McKenzie (USFS Pacific Northwest Research Station), Alina Cansler (University of Washington) and myself. Included are two oral sessions and a poster session, all on Tuesday, December 9. CIRMOUNT’s mentor organization, the international Mountain Research Initiative, hosts sessions on “Environment and Ecosystem Changes in the Third Pole and Other Mountain Regions” and “Accelerated Warming at High Elevations: Evidence, Processes, and Future Projections”. Find session information on the AGU website <http://fallmeeting.agu.org/2013/scientific-program-2/>

On behalf of the CIRMOUNT coordinators, I am excited to extend an invitation to attend *MtnClim 2014*, our flagship mountain-climate conference. The meeting will convene September 15-18, 2014 at the Homestead Resort in Midway, UT, in the high Wasatch Range, 1 hr drive from Salt Lake City. We are pleased to celebrate the 10th anniversary of the *MtnClim* meetings, with the first having occurred in North Lake Tahoe, California in 2004. In addition to field trips, talks, posters, and discussion within the meeting, *MtnClim* conferences are an opportunity to convene additional satellite work-group meetings.

If you’d like to do so, feel free to contact me and I can help with logistics. A post-conference workshop for managers focused on forest health and climate in the eastern Great Basin is in planning. Deadlines for registration and abstract submission for *MtnClim 2014* are not until July 15, 2014, but, as we limit attendance to 120, I encourage early registration. See more information on the program and venue on page 45; the conference website is: <http://www.fs.fed.us/psw/mtnclim/>

In this issue we feature an article on TOPOFIRE (pg. 2), a new and very promising decision-support tool for assisting fire management in complex mountain terrain, and two articles on the alpine and arctic upper treeline ecotone. These include a monitoring program designed to gauge global response (pg. 6) and an intensive site-based experimental heating study (pg. 8). *Brevia* articles summarize recent publications, in this issue including one derived from the alpine treeline heating experiment (pg. 12), another on a novel study of adaptive behavior in American pika (pg. 14), and a third on early results with new technology to measure rock-glacier movement (pg. 18). Given a change in leadership of the international GLORIA program (Global Observation Research Initiative in Alpine Environments), I took advantage to interview the former and new directors, Georg Grabherr and Harald Pauli (pg. 21). Finally, for the *Voices in the Wind* section, this issue I posed a question about imperatives for mountain climate adaptation. CIRMOUNT colleagues contributed valuable insight through their replies (pg. 28).

I hope you enjoy these and other articles, news, and art contributions in the autumn 2014 issue. On behalf of the CIRMOUNT coordinators, I send best wishes for the upcoming holidays and for a long, snowy (I hope), and mountainous winter.

– Connie Millar, Editor



Photo: S. Strachan

TOPOFIRE: A System for Monitoring Insect and Climate Induced Impacts on Fire Danger in Complex Terrain

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Wildfire Management in Complex Topography

Despite broad agreement that fire is an essential ecosystem component, fire management in the western U.S. mostly favors wild-fire suppression. A direct consequence of continued suppression is that most of the acreage burned in the U.S. burns during hot, dry conditions, making management more difficult and dangerous, and with more negative ecological effects. Recent mountain pine beetle outbreaks in the west dramatically alter fire behavior, adding additional complexity to fire management operations. Wildfires are a major driver of landscape-scale vegetation change, and managing fires more safely and effectively poses a daunting challenge in the face of expected warming and drying in the western U.S. that will likely result in more frequent fires with greater area burned. Data and tools that facilitate more proactive fire management are needed.

The primary limitation of available wildland fire management decision-making tools is that they ignore many spatial and temporal fire environment variations, particularly in regions of complex topography. The fire environment is loosely defined by three factors: fuel, weather and topography. Fuel and weather vary strongly both seasonally and spatially. Many weather factors such as temperature, humidity, wind, radiation, precipitation and snow cover influence ignition probability and regulate the behavior of that fire upon ignition. These conditions vary dramatically in complex terrain (Holden and Jolly 2011). However, operational fire management tools like the National Fire Danger Rating System (NFDRS) and fire behavior simulations performed in the Wildland Fire Decision Support System (WFDSS) are applied using input data from a single point, (usually the nearest Remote Automated Weather Station [RAWS], which may be many miles distant from the actual fire location) and these conditions are assumed to be representative of the landscape-scale conditions where decisions are being made. Even basic questions like how delayed snowmelt timing and cooler temperatures on north-facing slopes influences fire spread rates have never been addressed.

This represents a huge fire management knowledge gap that could dramatically alter how and where we manage or suppress wildfires if it were fully addressed.

With support from NASA, scientists from the U.S. Forest Service, the University of Montana, and University of Idaho have developed a prototype, open source, interactive web server called Topofire (topofire.dbs.umt.edu), designed as the next generation of the Wildland Fire Assessment System (WFAS). The overall goal of Topofire is to integrate NASA remote sensing and climate products into a decision support tool to rapidly synthesize and deliver high spatial resolution hydrologic and fire potential information to support both tactical and strategic fire management decisions. Data on the Topofire server can be viewed, queried and downloaded by watershed, predictive service area, or user-defined region (Fig. 1).

Climatic and Hydrologic Downscaling

A primary goal of Topofire is to integrate fine-scale spatial variation in temperature, humidity and snowmelt timing on fire danger estimates. The prototype Topofire server provides a suite of climatic, hydrologic and fuel moisture models for the U.S. Northern Rocky mountain region. To better address the influence of insolation and cold air drainage on surface air temperature, we leverage data from more than 2000 low-cost temperature and humidity sensors (Holden et al. 2013) distributed across the Pacific Northwest and Canada from 2009-2012. The hourly 1/12th degree National Land Data Assimilation System (NLDAS2) is ingested each day. These relatively coarse grids are downscaled to 240 meters using empirical models derived from relationships between sensor network data and coarse resolution gridded climate data. Topofire implements the FASST hydrologic model (Frankenstein and Koenig 2004), using inputs that include terrain adjusted temperatures, wind simulations from WindNinja, terrain and cloud corrected solar radiation, overstory vegetation characteristics, as well as soil type and depth. An example gridded FASST soil moisture map is shown in Fig. 2.

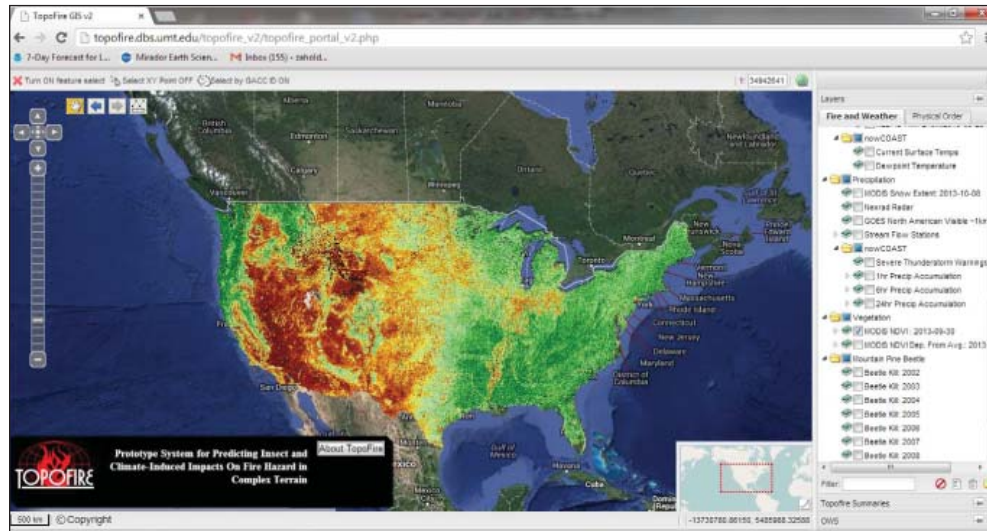


Figure 1. Topofire web interface showing MODIS NDVI relative greenness for October 16th 2013.

Mapping Potential Fire Behavior in Mountain Pine Beetle-Affected Areas

Recent Mountain Pine Beetle (MPB) outbreaks are affecting the surface and canopy fuel distributions across millions of acres of Western U.S. forests and these fuel changes can result in extreme fire behavior, particularly in the early “red” stages of attack. Fire managers currently rely on hand-drawn aerial survey maps for information on the location of beetle-killed areas. These maps generally represent last year’s conditions, and surveys usually miss large areas each year. Subjective differences between observers can also complicate analysis and limit utility. Accurate,

timely maps of historical and emerging insect-induced tree mortality are essential for safely and effectively managing wildland and prescribed fires.

We applied the Breaks For Additive Seasonal Trend algorithm (BFAST; Verbesselt et al. 2009) to MODIS 240 m vegetation index data to estimate the year of MPB attack. We assessed the ability of the BFAST algorithm to detect historical year of MPB attack at 274 intensified Forest Inventory and Analysis (FIA) plots on the Helena National Forest, Montana, that were measured in 2005 and then re-measured in 2008-2010 following a massive pine beetle outbreak. The BFAST algorithm correctly predicts the year of MPB attack with 78% accuracy. When combined with aerial sketch mapping data, detection maps derived from MODIS data should improve the accuracy and spatial resolution of MPB maps used for fire management.

Linking Knowledge from Physics-Based Simulations to Operational Models at Landscape Scales

A key gap in our understanding about the influence of MPB-induced vegetation change results in part because operational fire models (e.g., FARSITE, FLAMMAP) are limited in their capability to address beetle kill effects, often significantly underestimating potential fire intensity. A new class of dynamic, physics-based fire models is better equipped to characterize fire behavior in such complex fuel situations. However, the computational demands of these models limit their use to small-scale research studies. There is thus a need to extend what we can learn from more detailed models to the broader landscape scales important to operational concerns.

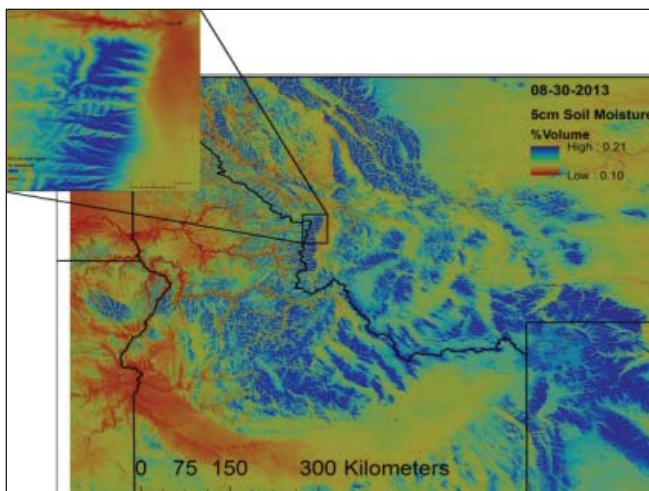


Figure 2. FASST modeled 5 cm soil moisture gridded output for August 13th 2013 for Idaho and Western Montana. Inset shows the Bitterroot Mountains.

To bridge this gap, we developed the MPB-LCP tool, which links information from physics-based fire behavior models to operational models. We first parameterized a set of detailed simulations at stand scales with physics-based fire models, using data from the 274 re-measured intensified FIA plots. We generated a series of realistic stands for physics-based fire simulations spanning different levels of canopy cover, tree mortality and wind speeds. We then developed a prototype application for a dynamic process that utilizes MODIS-derived year of attack maps to systematically modify fuels data used as inputs to operational fire behavior models. The basic concept of the system is to modify the Landscape file (.LCP) common to all spatial landscape scale operational fire behavior models. As a demonstration, we used the landscape fire model FARSITE to test the use of the MPB-LCP Modifier Tool for a small area within our larger study area. The area in question was heavily impacted by beetle attacks between 2006 and 2009. Using the same weather inputs, ignition location, and simulation duration, we modeled fire behavior for this test site, first with fuels inputs available from LANDFIRE, which do not include beetle attack effects, and then with fuels modified with the MPB-LCP Modifier Tool. The overall effect of the beetle attacks under this weather scenario, as predicted by the MBP-LCP Modifier Tool, was a doubling of the area burned and a significant increase in torching or passive crown fire (Fig. 3). Changes in spread rates at landscape scales were similar to those observed in the stand scale simulations. Many aspects of MPB attack effects on fuels continue to be an area of active research, but this work represents an important step in developing more robust fire modeling systems that provide the best decision support for community and firefighter safety and for more effective ecosystem management.

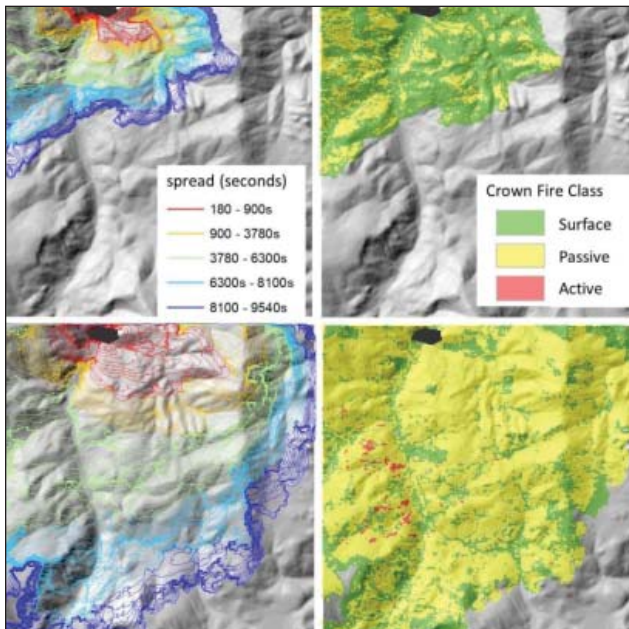


Figure 3. Results from a FARSITE fire behavior simulation. Two simulations were performed, one using standard conditions and a second incorporating a rate of spread multiplier derived from the MPB-LCP modifier tool.

Table 1. Expected products and deliverables from the Topofire project.

Product	Data source	Res	Frequency
Weather and Climate			
Bias corrected surface weather	NLDAS/PRISM	4km	Daily (1979-2XXX)
Terrain corrected surface weather	NLDAS/micromet	30m	Daily (1979-2XXX)
Downscaled real-time surface weather	NLDAS/micromet	240m	Daily
Fire Danger/surface hydrology			
Fuel moisture/fire danger grids	NLDAS/NFDRS	240m	Daily (1979-2XXX)
Surface/soil moisture grids	NLDAS/FASST	240m	Daily (1979-2XXX)
Ground temperature and humidity grids	NLDAS/FASST	240m	Daily (1979-2XXX)
Remote sensing derivatives			
NDVI Relative Greenness	MODIS	240m	16 day
MODIS snow cover	MODIS	500m	8 day
Disturbance maps	MODIS/aerial survey data	240m	16 day

Summary

The information being developed and distributed through Topofire has the potential to transform fire management decision making. Fig. 4 provides an overview of linkages between Topofire data and applications and fire management decisions.

Current fire danger assessments and fire management decisions ignore terrain effects on climate and the physical fire environment. Even if higher resolution data sources existed, operational fire models lack the capability to address fine-scale terrain induced variations in fuel moisture on fire behavior and fire spread. Refined estimates of fuel moisture that account for topoclimate, and fire behavior simulations that address the spatial heterogeneity in fuel moisture and structural conditions will provide a key missing source of information about how emerging fire incidents are likely to evolve, as well as the potential risks to life and property. In addition, high spatial resolution climate and hydrologic information have benefits that extend far beyond fire management. Ultimately, Topofire has the ability to greatly improve the situational awareness of wildland fire managers by ensuring that they have the most up-to-date fire environment information available when making time-sensitive decisions.

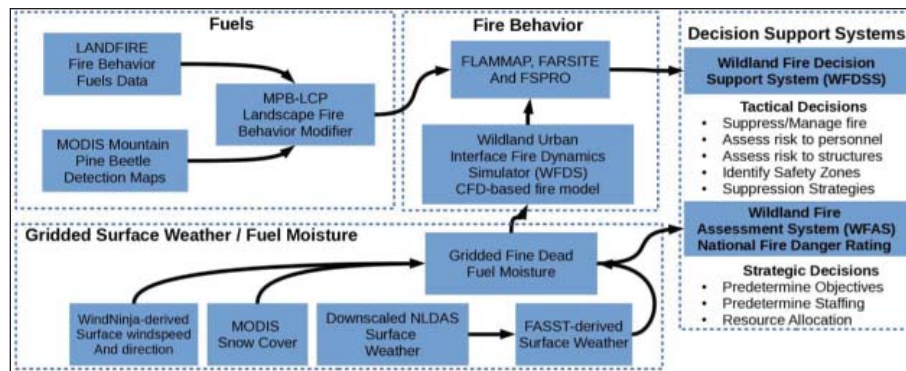


Figure 4. Major connections between Topofire remote sensing, high-resolution weather and fire behavior products to support wildland fire decision support.

Acknowledgements

Many people contributed to the development of Topofire and others are actively engaged in its continued development. We gratefully acknowledge: Susan Frankenstein (Cold Regions Research Lab), Anna Klene (U. Montana Dept. of Geography), Jason Forthofer, Kyle Shannon and Greg Cohn (Missoula Fire Sciences Laboratory), Solomon Dobrowski (U. Montana Dept. of Forest Mgmt.), Charles Luce (USFS Rocky Mountain Research Station), Marco Maneta (U. Montana Dept. of Geosciences) and Rob Keefe (University of Idaho). Funding for this project was provided by NASA Earth Sciences through a Wildland Fire Applications Grant.

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Pass Creek, Alaska. Photo: J. Littell

The Global Treeline Range Expansion Experiment

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The Global Treeline Range Expansion Experiment (G-TREE) is a globally distributed collaborative project aimed at testing the generality of mechanisms driving treeline position in subarctic and alpine systems. Using a straightforward experimental design with seeding and substrate-altering treatments, our goal is to disentangle biotic and abiotic limitations on treeline recruitment. This initiative will provide empirical data on where, and under what circumstances, treeline expansion can occur globally.

The idea for the Global Treeline Range Expansion Experiment was first developed at the final meeting of PPS Arctic, an International Polar Year (IPY) research group focused on treeline dynamics under climate change. One of the patterns documented via PPS Arctic research is perhaps better referred to as a lack of pattern, in that recruitment, growth, and infilling at our studied treeline ecotones was highly variable (Harper et al. 2011). Why are we seeing those patterns? What mechanisms are shaping treeline ecotones locally, regionally, and globally? Our group brainstormed ideas to move forward from our IPY findings into the next stage of treeline research and to keep the collaborative research network active. Our discussion focused on the following key points:

1. Testing the processes driving the patterns observed during IPY requires experimentation.
2. With the conclusion of IPY, continuing research in subarctic and alpine regions will require a new funding source, which can be slow and difficult to procure.
3. The IPY initiative trained a large cohort of early-career researchers, eager to continue with northern research but with fewer opportunities to do so.

Following that discussion, a small group established a set of hypotheses related to processes driving treeline position that could be experimentally tested (Brown et al. 2013). We first targeted recruitment of researchers who were working at annually visited research sites where costs associated with field logistics would already be funded (e.g., Wolf Creek, Yukon Territory, Canada; Fig. 1). The protocols for G-TREE were designed to be



Figure 1. The view of Coal Lake from the alpine zone of the Wolf Creek study area, Yukon Territory, Canada. Photo: Jill F. Johnstone.

efficient and cost-effective, minimizing the financial burden on participants, while yielding valuable data on treeline movement potential. We followed the model of previously established globally distributed experiments (Fraser et al. 2013), recognizing the need for global synthesis of easily comparable data on treeline systems.



Figure 2. View down the elevational gradient at Rif Blanc Forest, French Alps, towards closed forest stands dominated by *Larix decidua*, with *Pinus uncinata* and *Sorbus aucuparia* present. Photo: Hannah Loranger.

Our research network expanded with the addition of alpine research groups in Europe (Fig. 2), North America, and South America (Fig. 3), and the participation of individuals working at long-term monitoring sites around the world. G-TREE has truly been a collaborative network in that every member contributes to its development and success; thus, the G-TREE research design and protocols were improved by the invaluable contributions of all members. The addition of perspectives from researchers at European and tropical alpine sites has resulted in a set of protocols that can be implemented at any alpine or arctic treeline around the world.

A key component of the protocol design was to allow for various levels of commitment by participants. Level I protocols require the most basic seeding-substrate treatments, and would be appropriate for an undergraduate research project. Levels II and III have more complex treatment combinations, involving multiple species, provenances, and a herbivore-exclusion treatment (Fig. 4). Levels II and III were designed to contribute to a graduate student's research program, and are currently being undertaken by several graduate students around the world.



Figure 3. Tropical alpine forest at Sierra Nevada de Mérida in the Andes, Venezuela. Photo: Luis Daniel Llambi.

Currently, more than 30 researchers are actively participating in the global experiment, with many sites established this past summer, and collaborators in the southern hemisphere are now preparing their sites for their rapidly approaching field season. A second phase of G-TREE sites will be established during the 2014 field season, as will monitoring of sites initiated in 2013. To our knowledge, this is the most extensive globally-executed experiment on treeline expansion to date, and we look forward to expanding our network even further.



Figure 4. Esther Frei establishing Level III G-TREE protocols in the Swiss Alps, which includes a herbivore exclusion treatment. Photo: Christian Rixen.

Acknowledgements

The development of G-TREE was aided by the valuable contributions of and discussions with Jill F. Johnstone, University of Saskatchewan, Christian Rixen and Sonja Wipf, WSL Institute for Snow and Avalanche Research, Christian Körner, University of Basel, and all the members of the collaborative research network.

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Learn more about G-TREE at treelineresearch.com.

An Experimental Approach to Determining Biophysical Constraints to Western Subalpine Forest Regeneration and Migration with Climate Change

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Western forests are highly sensitive to global and regional climate variability and change, with increasing background mortality rates, increased frequency of large and severe wildfires, and increased exposure to mountain pine beetle, all linked to warmer temperatures or greater water stress (e.g., Westerling et al. 2006, van Mantgem et al. 2009, Logan et al. 2010). Further, the compound effects of global warming and natural climate variation have led to “global change type droughts” throughout the West, resulting in massive dieback of conifer forests (Breshears et al. 2005, Allen et al. 2010). Yet, little attention has been paid to how forest regeneration is affected by changing climate, that is, whether changes will alter tree seed production, seedling recruitment within present species ranges, and/or promote establishment of species beyond current upper and northern range boundaries, as predicted by simple bioclimatic envelope models (Rehfeldt et al. 2006). While the effect of climate on reproduction is a critical element that also needs further study, we have been examining how climate change may affect tree recruitment from seed, thereby altering future forest structure, composition, function, and distribution. We are linking seedling demography to biophysical constraints on seedling metabolism, growth and mortality, and are comparing results across species and high- and low-elevation provenances to better predict how subalpine forests respond to changing climate.

This basic research is critical input for vulnerability assessment and climate adaptation planning by resource and conservation managers. In topographically complex regions such as in Western mountains, simple expectations of upslope migration of climatically suitable habitat may not be adequate, and in particular, may underestimate opportunities for low elevation refugia and/or overestimate capacity for upper elevation shifts (Dobrowski 2011), while neglecting effects on ecosystem health and watershed functions from changes in forest density and structure (Dolanc et al. 2013). Upper treeline in the Western U.S. may be dynamically sensitive to changes in both temperature and soil water availability, with sensitivity dependent on topographic position, coincidence of radiation and water availability, and tree species. Seedlings, which are less buffered from climate and resource variability, may be more sensitive than adults. Thus, predicting transient and long-term forest responses to climate change requires knowledge of climate sensitivities throughout species’ life histories. To date, climate effects on regeneration have been a significant gap in knowledge, yet successful adaptation hinges on improved understanding of this key phase in forest development.



Figure 1. Upper subalpine site in fall 2010. Tall upright poles allow heaters to be raised above snow in winter. Photo: A. Moyes

Questions and Methods

For the last several years we have had three major research questions to focus our work.

1. Will subalpine trees recruit into current alpine habitat and replace, or coexist with, alpine plant species as a result of climate change?
2. Will subalpine tree recruitment be impaired in species' existing ranges as a result of climate change?
3. What ecophysiological, population genetic, and/or biogeochemical factors influence climate-induced changes in subalpine tree recruitment within and outside species' current ranges?

To address these questions, we established the Alpine Treeline Warming Experiment (ATWE) in 2008-2009, three sets of common gardens subject to factorial warming x watering treatments along an elevation gradient at Niwot Ridge, in the Front Range of the Colorado Rocky Mountains. The Alpine site is above current treeline and is potential habitat into which subalpine conifer species could recruit with future climate change. The Upper Subalpine site is in the alpine-treeline ecotone, near the climatically “cool” edge of subalpine forest (Fig. 1). This zone may remain marginally suitable or perhaps become more suitable for subalpine trees with climate warming. The Lower Subalpine site is just above the lower elevation, “warm” edge of subalpine forest (Fig. 2). This zone may remain suitable or become less suitable habitat with climate warming. Weather station data from 2010-2012 indicate that the snow-free period is approximately one month longer at the treeline site, where krummholz and flag trees act as snow fences to trap blown snow, than at either the alpine or lower subalpine site, and that sites differ by more than 6 m s^{-1} in average wind speed and 4.6°C in daily mean temperature, over the same period.



Figure 2. Miles Daly waters a heated and watered plot in the lower subalpine forest site in September 2010. Photo: L. Kueppers

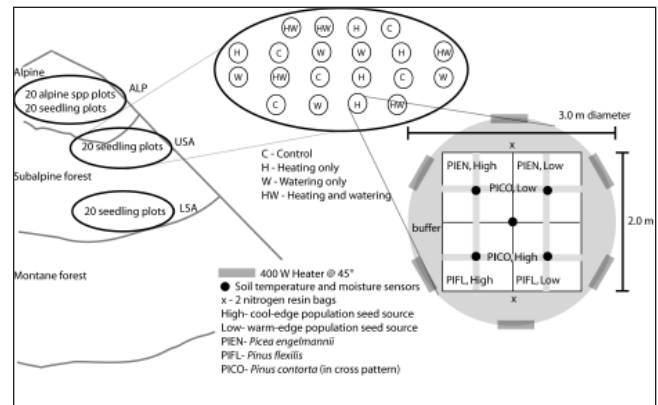


Figure 3. Schematic of the Alpine Treeline Warming Experiment (alpine spp plots not described here). Each year, sixty seedling plots are sown with high- and low-elevation limber pine and Engelmann spruce (in four separate quadrants), and high- and low-elevation lodgepole pine (in two-way transects through the middle of two quadrants each). Diagram: L. Kueppers

Each site has 20 3-m diameter plots with 5 replicate plots assigned to each of four groups: Control, Heated, Heated + Watered, and Watered. Overhead IR heaters set to a constant output are used to advance the timing of snowmelt and elevate plant and soil temperatures during the snow-free season. Watering rates (applied manually each week during the growing season) have been 2.5 mm wk^{-1} since 2010, an amount meant to compensate for the drying effects of heating. We installed ECTM and 5TM soil moisture and temperature sensors (Decagon Devices) at 5-10 cm and 15-20 cm depth and record soil microclimate conditions every 15 minutes. Each experimental plot is divided into four adjacent 1 m^2 quadrants, which are sown each fall with two of six seed types: *Picea engelmannii*, *Pinus flexilis*, and *Pinus contorta* collected locally from near treeline (11,000 ft) and near the lower limit of subalpine forest (10,000 ft) (Figs. 3, 4). We track the number of seeds sown and number of seedlings surviving to October and to just after snowmelt each year to quantify treatment effects on 1st, 2nd and 3rd year survival, differentiating winter from summer mortality. We maintain hardware cloth cages over quadrants to limit (albeit imperfectly) granivory and seedling herbivory.

Initial Findings

In fall 2008 (prior to active climate manipulations), we sowed a subset of the plots with *P. flexilis* and *P. engelmannii* seed, and in spring 2009, also sowed the same plots with greenhouse-started transplants. Both species emerged at very low rates ($<10\%$) in the alpine, with zero survival of *P. engelmannii* germinants and low (2%) survival of *P. flexilis* to the end of the 2nd season (Castanha et al. 2012), indicating strong bottlenecks to tree

recruitment in the alpine during both germination and early seedling survival. Emergence and survival were stronger in LSA and USA, but only ~4% of *P. flexilis* emergents survived to the end of the 2nd growing season (Castanha et al. 2012), indicating a stronger survival than germination constraint. Ecophysiological measurements on the transplanted *P. flexilis* seedlings suggest that they are able to assimilate carbon at high rates in the alpine – higher than at the other two sites – suggesting lack of a significant cold limitation to carbon uptake in the alpine during the core growing season (Reinhardt et al. 2011). At the same time, warming can diminish *P. flexilis* seedling carbon gain at all sites by reducing surface soil moisture, which reduces stomatal conductance and carbon assimilation (Moyes et al. 2013). Further, first year *P. flexilis* seedling survival is correlated with surface soil moisture even at and above treeline and is inversely related to longer, warmer growing seasons (Moyes et al. 2013), effects exacerbated by heating. Understanding the interacting ecophysiological mechanisms that yield microclimate constraints to seedling emergence and survival, and how they vary by species and population, is a primary research priority.

Ongoing and Planned Work

Ongoing work at this unique experimental facility includes analysis of multi-year seedling demographic outcomes, quantification of ecophysiological stress thresholds for all three species, genetic comparisons of high- and low-elevation provenances using single nucleotide polymorphisms (SNPs), development of models that link population demography with biophysical thresholds to estimate climate change effects on population structure, and examination of soil microbial



Figure 4. Jon DeCoste sows conifer seed collected in 2012 and 2013 into an experimental plot at the upper subalpine site in October 2013. Photo: W. Brown.

community and soil nitrogen responses to manipulations. Plans for the next phase of work include adjustments to heating and watering manipulations to better quantify demographic thresholds (e.g., for an extreme wet year), examination of genetic filtering by site and treatments using SNPs, and testing a conceptual model relating demography, root growth and belowground microclimate over the growing season. We also look forward to making our results useful to the land management community as scientists and managers work together to develop adaptation strategies in the face of climate change.

Information on the ATWE can be found at <https://alpine.ucmerced.edu/pub/htdocs/>. The project has been funded by the DOE Office of Science, and is a collaboration among PIs at multiple institutions: L. Kueppers (UC Merced, LBNL), J. Harte (UC Berkeley), M. Torn (UC Berkeley, LBNL), M. Germino (USGS), and J. Mitton (Univ Colo, Boulder).

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View enroute to the Niwot Ridge Long Term Ecological Research site during the autumn *MtnClim* 2012 field trip.
Photo: C. Millar

BREVIA

Moisture Limitation to Tree Establishment Extends All the Way Up into the Alpine Zone

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Moyes, A., Castanha, C., Germino, M., and Kueppers L. 2013. Warming and the dependence of limber pine (*Pinus flexilis*) establishment on summer soil moisture within and above its current elevation range. *Oecologia* 171:271-282.

Climate change is projected to alter the geographic distributions of mountain plant species, in part by affecting where individuals can establish from seed. Subalpine conifers of the western United States grow slowly after germination, and seedlings are likely to face limitations associated with the near-surface environment, particularly at their high and low elevation distribution boundaries. In their recent paper published in the journal *Oecologia*, Moyes et. al tested the hypothesis that warming promotes uphill redistribution of subalpine tree populations by reducing cold limitation at high elevation and enhancing drought stress at low elevation.

The study was part of the alpine treeline warming experiment (ATWE, <https://alpine.ucmerced.edu/pub/htdocs>) at Niwot Ridge in Colorado's Front Range (see page 8). In the ATWE, collaborators from UC Merced, UC Berkeley, and the U.S. Geological Survey are sowing seeds of limber pine (*Pinus flexilis*), Engelmann spruce (*Picea engelmannii*) and lodgepole pine (*Pinus contorta*) into common garden plots with treatment combinations of infrared heating and summer water addition, at sites positioned in lower subalpine forest, the treeline ecotone, and alpine tundra (Fig. 1). During the snow-free growing season, infrared heaters raise average soil temperature by around 1.5-4.5 °C.

Moyes et. al assessed first-year limber pine seedlings at all three sites for physiological performance and survival until the end of the 2010 growing season, a year with near-average precipitation.

Seedlings emerged in midsummer, about 5–8 weeks after snowmelt. Low temperature was not observed to limit seedling photosynthesis or respiration between emergence and season's end, and thus experimental warming did not appear to reduce cold limitation at high elevation. Instead, physiological measurements (photosynthesis, respiration, and midday stem water potential) from all sites indicated a prevailing effect of summer moisture stress on photosynthesis and carbon balance. Despite marked differences in vegetation cover and meteorological conditions across sites, volumetric soil moisture content below 16 and 8% consistently corresponded with moderate and severe indications of seedling drought stress. Seedling survival was greater in watered plots than in heated plots, and negatively related to soil growing degree days (integrated soil temperature over the growing season, Fig. 2) and duration of exposure to soil moisture below 8%.

The authors concluded that seasonal moisture stress and high soil surface temperature imposed a strong limitation to limber pine seedling establishment across a broad elevation gradient, including above alpine treeline, and that these limitations are likely to be enhanced by further climate warming. This was contrary to expectations that soil moisture would be abundant near the upper tree limit, and shows a potential for drought effects of warming to offset the benefit of alleviating cold limitations at high elevation. A greater importance of heat and drought stress during seedling establishment would complicate predictions of future uphill forest advance based on historic cold limitation alone.



Figure 1. Photograph of the alpine site (above treeline), one of three sites that span an elevation gradient from forest (3,060 m, 10,040 feet) to alpine (3,540 m, 11,615 feet). At each site warming and watering treatments are applied to 20 common garden plots, within which subalpine conifers are seeded each year. The photo was taken in late summer, when heat and moisture stress were occurring, leaving tundra vegetation dry and senescent or dormant.

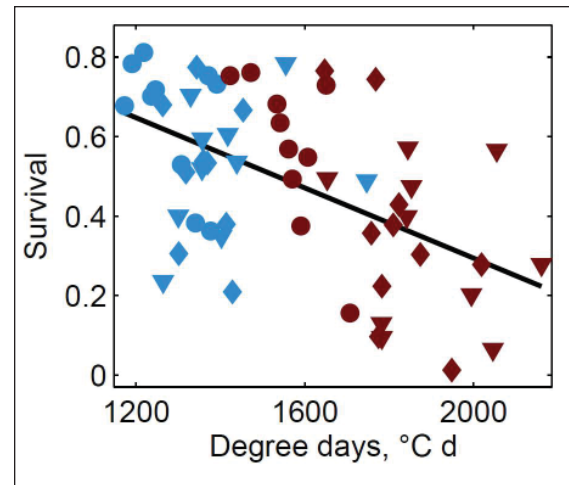


Figure 2. Survival of first-year seedlings of limber pine decreased with growing season degree days, an integrated measure of temperature exposure over the entire growing season. Temperature data were from sensors buried vertically to measure average soil T at 5-10 cm. Red symbols are from heated plots and blue symbols are from unheated plots. Shapes indicate site: circles were alpine, diamonds were at treeline, and triangles were from lower subalpine forest.



Upper subalpine site in October 2013. Photo: W. Brown.

BREVIA

Large-Scale Foraging Behavior in the American Pika: Linking Behavior and Environment

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Smith, J. A. and L. P. Erb. 2013. Patterns of selective caching behavior of a generalist herbivore, the American pika (*Ochotona princeps*). *Arctic, Antarctic, and Alpine Research* 45(3):396-403.

The American pika (*Ochotona princeps*) has become a species of interest in recent years due to its predicted responses to climate change (Beever et al. 2011, Erb et al. 2011). There is growing concern and controversy regarding the ability for pikas to persist in a warming world due to their sensitivity to high temperatures (Smith 1974, Wilkening et al. 2011, Beever et al. 2011). Although much of the current research on pikas either employs survey techniques to detect presence (Erb et al. 2011) or uses climate modeling to predict future available habitat (Calkins et al. 2012), understanding pika behavioral responses to environmental variability is essential for the prediction of the impact of climate on pika population persistence. To our knowledge, little to no recent work has been conducted to examine behavioral responses of the American pika to environmental factors related to climate.

Foraging and caching behavior has been well studied in the American pika. Because they do not hibernate, pikas cache vegetation in haypiles during the summer months in order to build a food reserve for harsh winter conditions in which they cannot forage (Fig. 1). As a species, pikas are considered generalists and do not specialize on particular plant species (Ivins 1984, Smith and Weston 1990), although individual populations exhibit selective foraging behavior among available vegetation. Researchers examining many different populations of pikas have documented a variety of patterns in pika selective foraging and caching. These patterns include selection of plant size and morphology (Huntly et al. 1986, Hudson et al. 2008), spatial distribution of plants (Kreier 1965, Millar and Zwickel 1972, Roach et al. 2001, Morrison 2007), nutrition (Millar and Zwickel 1972, West 1980, Morrison 2007), presence of secondary compounds (Dearing 1996, Dearing 1997, Gliwicz et al. 2006), and novelty (Ivins 1984). Many of these studies not only attribute selectivity to different plant characteristics, but contradict the findings of those proposed by others. However, each of these studies was conducted at only one site or two neighboring sites. Given the wide diversity of habitats in which pikas

live, we sought to investigate potential relationships between environmental variables and selective caching behavior (Smith and Erb 2013).



Figure 1. Pika haypile dominated by graminoids and *Castilleja occidentalis*. Photo: J.A. Smith

Foraging is one of the most fundamental behaviors for individual survival, and selection of forage often depends on the quality of other available resources in the environment (Stephens and Krebs 1986). Foraging behaviors are predicted to change based on energetic and nutrient requirements, internal stress, and time restrictions. Pikas throughout the southern Rocky Mountains experience a wide array of environments characterized by differing vegetation communities, precipitation types, frequencies, and intensities, average and maximum temperatures, and presence or absence of rock-ice features. These site-specific differences are likely to influence the levels of heat stress, activity budgets, and limiting nutrients of individual pikas, potentially altering selective preferences among populations. However, because of the limited spatial scale of previous work on pika caching behavior, pika forage selection is understood only with respect to the particular environmental conditions present in each independent study. Our research begins to examine differences in selective caching with respect to environmental variation.

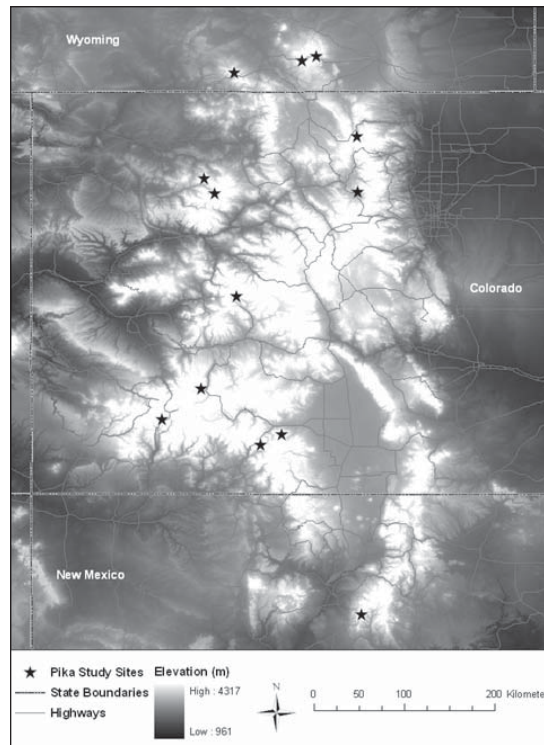


Figure 2. Map of 13 study sites in the southern Rocky Mountains. From Smith and Erb 2013.

We investigated large-scale patterns of selective caching to determine which characteristics of plants showed evidence of selection and which environmental variables correlated with patterns of observed selectivity (Smith and Erb 2013). Our study included 13 historical pika sites that ranged across three states and 600 m of elevation (Fig. 2). For this analysis, we chose two features of plant quality that have been examined in the literature with conflicting results: water and nitrogen content. Because of the large spatial scale of our study and a desire to sample each site at approximately equivalent phenological stages, we were unable to collect data on plant morphology or spatial structure

and restricted our measures of quality to nutritional variables. The environmental variables investigated included total annual precipitation, mean summer temperature, elevation, and latitude. (For further information on sampling design and analytical methods, see Smith and Erb 2013.)

Our results indicate that pikas differentially select vegetation for their winter haypiles with regard to both the external environment and the quality of available vegetation (Fig. 3). However, they may select for characteristics of vegetation using different environmental cues. In particular, we found that although pikas nearly always select for higher water and nitrogen content, they reduce the degree of selectivity for nitrogen as it becomes more available in the environment. In contrast, the magnitude of selection for water content remained constant despite the water content of available plants. Selectivity for high water content was negatively correlated with elevation, and selectivity for high nitrogen content was positively correlated with average summer temperature (Fig. 4). Neither elevation nor average summer temperature were correlated with available vegetation quality, indicating that the selectivity was a function of the environmental factor rather than its relationship to available vegetation.

Explanations for the patterns observed are derived from known interactions between pikas and their environment. We propose that lower activity levels in hot environments (Smith 1974) may promote greater selectivity of high quality foods at high ambient temperatures to compensate for reduced caching time. The tradeoff between thermal regulation and foraging behavior should be further studied to investigate this hypothesis. The relationship between water content selectivity and elevation may be a result of differential seasonal variability in water availability at low and high elevation sites. High elevation sites often have longer periods of snowpack and greater prevalence of rock-ice features, both of which provide consistent free water sources (Millar and Westfall 2008, Millar and Westfall 2010). Although pikas have occasionally been observed to consume free water, the prevalence

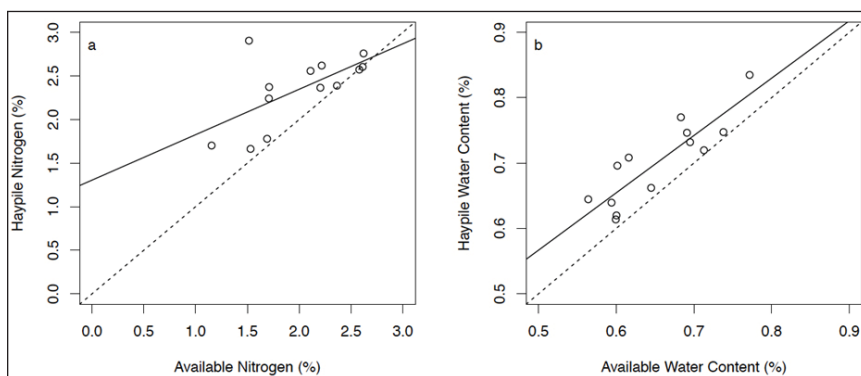


Figure 3. Haypile quality as a function of abundant available vegetation quality for a) nitrogen content and b) water content. The dashed line represents the expected relationship given no selectivity. Each point represents the weighted average quality at an individual study site. Haypile quality was higher than available vegetation with regard to both nitrogen content ($p < 0.01$) and water content ($p < 0.001$). Selectivity for nitrogen content declined as it became more available in the environment ($p < 0.05$). From Smith and Erb 2013.

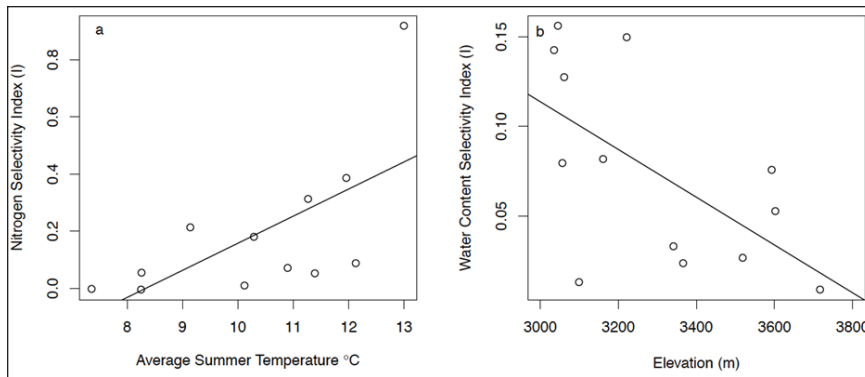


Figure 4. Relationships between (a) nitrogen content and mean summer temperature ($R^2 = 0.433$, $p < 0.05$) and (b) water content and elevation ($R^2 = 0.366$, $p < 0.05$). From Smith and Erb 2013.

of the behavior is unknown (C. Ray pers. comm.). Low elevation sites without reliable water sources may foster greater selectivity for forage with high water content.

Although more work is needed to test the mechanisms of selection, we have described for the first time that pika caching decisions are variable over space and are correlated to environmental conditions. Pika caching behavior appears to be complex and may respond to both internal state and external conditions. This result provides insight into how pikas may respond to changing climatic conditions in the southern Rocky Mountains with regard to their foraging behavior. However, due to the limited temporal scope of this study, we did not examine climate change explicitly. Instead, we chose to explore spatial variability in selective caching and its relationship to environmental heterogeneity to investigate potential drivers of selective caching. To further explore relationships between climate and caching behavior, research integrating haypile quality, climate, and pika overwinter survival is needed.

In this initial study of patterns of selective caching behavior across an extensive elevational and latitudinal gradient, we hope to have set the groundwork for further studies of differential foraging decisions over longer temporal scales. Due to the American pika's diverse behavioral profile and apparent foraging plasticity, future work on the relationship between pikas and climate should bridge foraging decisions with their ramifications on fitness and persistence in dynamic and changing landscapes.

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Pika haying. Photo: J.A. Smith

BREVIA

Taking a Census of California Rock Glaciers from Space

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Liu, L., Millar, C., Westfall, R., and Zebker H. 2013. Surface motion of active rock glaciers in the Sierra Nevada, California, USA: Inventory and a case study using InSAR. *The Cryosphere* 7: 1109-1119, doi:10.5194/tc-7-1109-2013.

Rock glaciers are abundant throughout cirques and valleys of the central and southern Sierra Nevada ranges (Millar and Westfall, 2008). Active rock glaciers creep downslope cohesively as a consequence of the deformation of internal ice (Haeberli et al., 2006). Their kinematic states are of scientific interests because the spatial and temporal changes of surface flow are indicators of changes in regional and local climatic conditions. However, most rock glaciers are remotely located, making it difficult to measure their surface flow in the field. We applied a remote sensing tool named Interferometric Synthetic Aperture Radar (InSAR) to radar images obtained by a Japanese satellite from about 700 km altitude to map surface speed at 59 active rock glaciers in the region. The inventory we compiled describes the kinematic state of these rock glaciers and is available online at <http://www.the-cryosphere.net/7/1109/2013/tc-7-1109-2013-supplement.zip>

What is InSAR?

By measuring phase differences between two radar images taken at different times, InSAR makes an interferogram that maps ground surface motion in the satellite's line-of-sight direction during the time interval of the radar images. Such a map of ground motion covers a large area (typically 100 km by 100 km) with a high accuracy at the centimeter to millimeter level and with a high spatial resolution of tens of meters. Although InSAR has become a standard tool in geophysical studies such as earthquake and volcano deformation (Bürgmann et al., 2000), its applications in alpine studies remain scarce. In this study, we show that the InSAR technique has the potentials of both mapping rock glacier motions in a regional-scale and providing detailed, high resolution imaging in both space and time.

Rock Glacier Inventory

The key dataset of our inventory is rock glacier surface spread, plotted as a snapshot in late summer of 2007 in Fig. 1. The regional-mean speed was 53 cm/year (annual equivalent). Spatially, our inventory shows that active rock glaciers tend to cluster, implying a significant influence of regional conditions such as climate and topography on their occurrence. Moreover, rock glaciers in the southern Sierra Nevada moved faster with a larger spatial variability than those to the north.

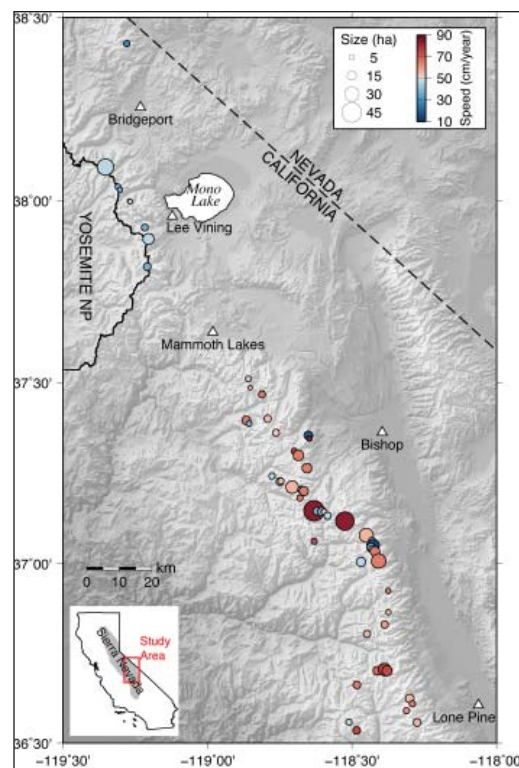


Figure 1. Map of active rock glaciers in the Sierra Nevada of California. The size and color of the circles represent the size and speed of the rock glaciers, respectively. The flow speed estimates are for the late summer of 2007.

Table 1. Summary of the active rock glaciers in the Sierra Nevada based on InSAR.

Mean elevation (m)	3551
Elevation range (m)	3077–3787
Mean size (ha)	13
Size range (ha)	3–46
Mean length (m)	624
Mean width (m)	201
Mean length-to-width ratio	3.3
Mean speed (cm/year)	53
Speed range (cm/year)	14–87

In addition to surface speed, our inventory also documents the size, geometry, elevation, moving direction, and aspect ratio of these active rock glaciers. Table 1 summarizes the regional mean of major parameters. Azimuth distribution is predominantly in the N-NE direction, controlled by the aspect of solar radiation and snow accumulation.

A Case Study of the Mount Gibbs Rock Glacier

Compared with field measurements, InSAR provides a more spatially complete assessment of the surface flow at individual rock glaciers in fine spatial and temporal details. We demonstrated this potential using the Mount Gibbs rock glacier as an example. This is a tongue-shaped rock glacier located in Gibbs Canyon along the eastern escarpment of the Sierra Nevada, 10 km southwest of Lee Vining. Transverse furrows and longitudinal ridges are visible along two lobes in the middle and lower parts (Fig. 2a).

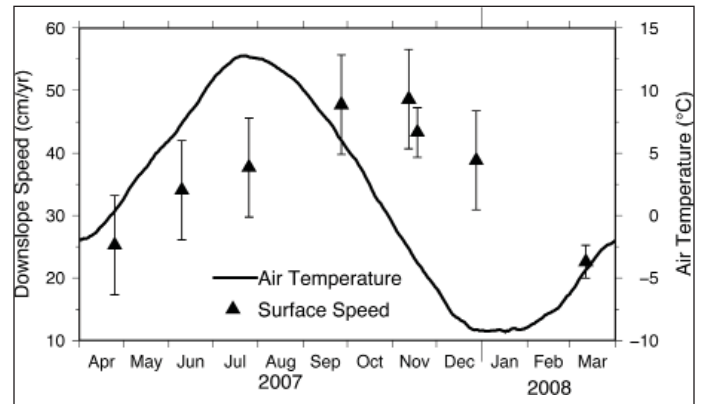


Figure 3. Time series of the InSAR-estimated speed at the cross marker on Fig. 2b (triangles with error-bars). Surface speed lagged about three months behind air temperature (solid line, one-month moving averages of daily temperature records)

High-resolution (10 m) InSAR maps such as the one shown in Fig. 2b reveal high speeds of 50 cm/yr at the furrow-ridge system and stable areas such as the southeast flank and the depression area between the two flowing branches. Using a series of radar images taken every 46 days in 2007 and 2008, we were able to produce time series of the surface motion (Fig. 3). It shows a strong seasonal variation of surface speed, more than double in the fall from its minimum in the spring and lagged about three months behind the seasonal cycle of air temperature variations. Our findings suggest the necessity of long and dense observation records to separate long-term changes in rock glacier kinematics associated with climate change from seasonal variations.

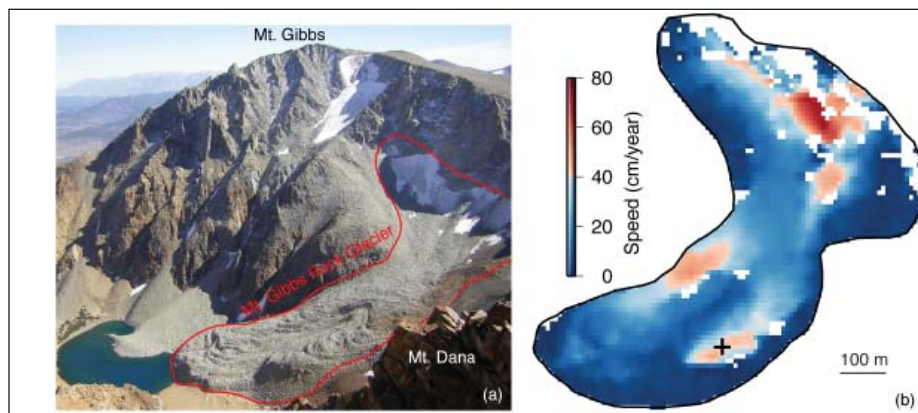


Figure 2. The Mount Gibbs rock glacier (a) and its surface speed during September-December 2007 (b). White areas within the black boundary are places where no reliable InSAR measurements could be made.

Open Questions

Further studies are required to elucidate the underlying geomorphological mechanisms for a few of our key findings. For instance, we found that rock glacier speeds are higher in the southern than in the central Sierra Nevada, implying strong influences of local factors such as thickness, ice content, hydrological conditions, and debris content. But it remains unclear which factors play a major role in this spatial difference. What causes the strong seasonal variations in speed at the Mount Gibbs rock glacier? Simple thermal-kinematic-couple models such as the one used by Kääb et al. (2007) could not explain the magnitude or the phase we observed in this study.

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Bristlecone pine skeleton, White Mtns, CA. Photo: S. Weiss

An Interview with the Founders and Leaders of GLORIA: The Global Observation Research Initiative in Alpine Regions

Change is underfoot at the Vienna, Austria headquarters of GLORIA, and that bodes well for the future of this global mountain observatory program. Pioneering scientist Georg Grabherr, who brought the GLORIA program into international status and has been Director since the program's start, has recently retired, while Harald Pauli, long-time scientist with the program who documented early responses in alpine flora to climate change and helped develop the GLORIA protocol, has assumed Georg's role as Director. These transitions have been seamless for the worldwide GLORIA network, which looks to Vienna for coordination and program mentorship. The recent activities in Vienna seal a strong future for this critical alpine monitoring program. I took the occasion to interview Georg and Hari on their retrospective and prospective views for GLORIA.

– Editor

The GLORIA coordination office is located at the Department of Conservation Biology, Vegetation and Landscape Ecology, University of Vienna, Vienna, Austria

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

GLORIA North America: www.fs.fed.us/psw/cirmount/gloria/

Back Story (adapted from the International GLORIA website)

The purpose of GLORIA (the Global Observation Research Initiative in Alpine Environments) is to establish and maintain a world-wide, long-term observation network in alpine environments. Vegetation and temperature data collected at the GLORIA sites are used for discerning trends in species diversity and temperature.

GLORIA goals are to document changes in biodiversity and vegetation patterns caused by climate change in the world's high mountain ecosystems. GLORIA aims to collect high-quality baseline and monitoring data by establishing: 1) a multi-site and long-term monitoring network, comprising Multi-Summit Target Regions, which are established at a world-wide level; and 2) a network of sophisticated long-term research sites, the GLORIA Master Sites, which promote integrative research on alpine responses to climate change.

The strength of the GLORIA network is its simple approach, which is to promote the establishment of a large number of sites within and across continents. The establishment and long-term maintenance of such a large-scale, multi-site network requires a world-wide community of committed ecologists. It wholly depends on researchers who are willing to establish the foundations of a long-term program, which yields results for future generations. The development of GLORIA is an ongoing process, and individuals and institutions with an interest in

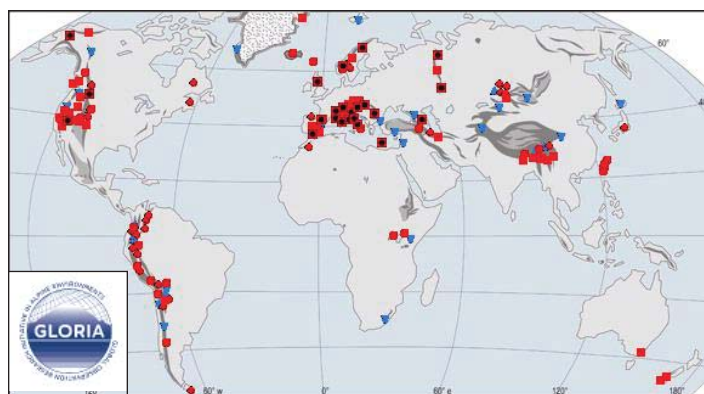


Figure 1. Worldwide GLORIA sites.

ecological research in alpine environments are welcome to contribute. GLORIA site managers are responsible for the establishment and maintenance of sites, and for using the standardized GLORIA protocols.

Coordination of GLORIA is undertaken by the GLORIA Office at Vienna and includes the following:

1. Scientific coordination, supervision, and support of field work and data analysis in cooperation with GLORIA site managers and researchers;
2. Administration and technical communication with network members;
3. Maintenance and development of the central GLORIA database and communication structures; implementation and coordination of GLORIA-related research projects;
4. Building and consolidating interfaces to other networks and programs in the area of global change research, and to inter-governmental research bodies; and
5. Raising the level of public awareness of the ecological implications of climate change.



An Interview with Georg Grabherr and Hari Pauli



Georg Reflects:

Connie: When did you first consider developing the idea for an international network to monitor response of alpine plants to climate change, and what prompted this idea?

Georg: Soon after taking the chair as professor of Conservation

Biology, Vegetation and Landscape ecology at the University of Vienna in 1986 I met by chance Al Solomon, who just had just been appointed to direct the programme at IIASA* for developing a sustainable model on how vegetation might react to climate change. He invited a strong group for a brainstorming session (including, among others, D. Billings, I. Woodward, H. Shugart, and C. Körner) to discuss basics for the requested modelling. Core scientists executing these ideas at the time included C. Prentice, W. Cramer, and R. Leemans, who, subsequently become key leaders in climate change research. Thinking about how to contribute, I remembered Braun-Blanquet's paper on floristic changes on Piz Linard, the highest summit of Silvretta at the border between Austria and Switzerland. Just at the same time two young students, H. Pauli and M. Gottfried, came across me, asking for opportunities to conduct mountain ecological research. We repeated Braun-Blanquet's approach, and found that species richness at the limits of plant life had increased, indicating that the already observable warming was also ecologically effective. To our surprise we got these results published in *Nature* (Grabherr, Gottfried, and Pauli 1994). Our paper was recognised widely by the research community and also in the media (e.g. New York Times, USA Today, front page).

This overwhelming response was the stimulus to think about an extension to Europe and, finally, to a global network. A broad request to the international scientific community, asking for the willingness to jointly build a global observation network on climate-change impacts on alpine plant diversity, yielded a tremendously positive response. GLORIA was in essence born in this manner, though at the time not named as such. GLORIA, as an acronym for "Global Observation Research Initiative in Alpine Environments", was used for the first time in the project proposal to the European Union research programme in 1999. We proposed a pilot study to test the newly advanced monitoring methodology in the major mountain regions of Europe. In the evaluation process, we succeeded with a rating close to the Maximum. There were 18 research groups involved. The two students became – so to say – the GLORIA masters since**.

*IIASA International Institute for Applied System Analysis; Laxenburg; Austria

** Unfortunately, Michael Gottfried suffered a major stroke last year, and, probably, will not return to work



Georg in Glacier National Park, MT at a 2013 GLORIA - North America mini-summit. Photo: C. Millar

Connie: The GLORIA Multi-Summit target-region approach has proven highly effective in monitoring change in the alpine zone, and expandable worldwide to many mountain regions. Can you explain how the monitoring protocol was developed? Did you engage alpine scientists from around the world? What was the process you used to develop a consensus approach?

Georg: The most important lesson we learned after revisiting more than 30 summits in 1992-1993 was that precise positioning is essential. Harald Pauli reviewed the study designs from more than 200 publications, but for only about 35 summits had any of those researchers monitored essential data, e.g., at what elevation they started the surveys. Usually monitoring plots were set on a mountain slope following the elevation gradient from upper treeline up to the nival zone ("transect" or "single slope" approach). As an alternative Harald Pauli and Michael Gottfried developed what we later called the "Multi Summit approach". Summits at different elevations in a "Target Region" are selected as sample sites, and 16 quadrats near the top are placed in 4 clusters exposed to the four cardinal directions (Fig. 2).

From its very start, the GLORIA monitoring protocol was designed in view of a globally applicable approach along three core principles:

COMPARABILITY: Summits with standard plots as comparison units;

SIMPLICITY: A clearly defined protocol, readily repeatable;

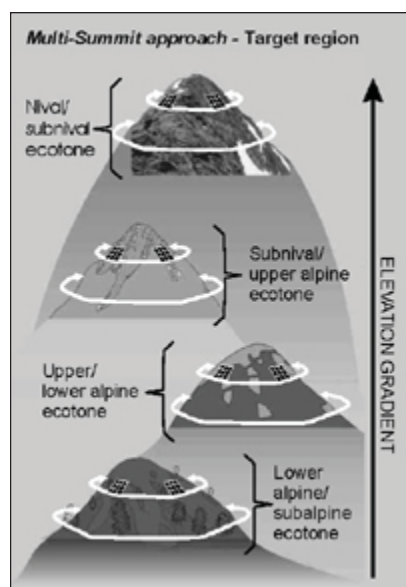
CHEAP/TIME SAVING: Access to long-term funding is usually not available; at the uppermost sites the vegetation period suitable for recording does not last longer than 2-4 weeks.

Considering these principles and our combined field experiences, we developed rules such as:

- How to select mountain systems as Target Regions (same geology and climate);
- How to design a plot arrangement at the summits that provides adequate statistical power (list of species of vascular plants, optional mosses, lichens);
- What to list and count (observer error, sparse species, “the log-normal devil”, species identification);
- How and what kind of temperature measurements should be performed;
- How to handle the data.

To adapt, and/or improve rules, the GLORIA coordination team organised meetings or sent out circulars. Most of this coordination work was financed by European funding (Pilot-project “GLORIA-Europe”). GLORIA has had close links to international programmes such as IGBP, MAB, MRI-GLOCHAMORE, and GMBA.

Figure 2. GLORIA Target Region design.



Connie: What would you consider the greatest success of the GLORIA program to date?

Georg: There are several milestones that should be mentioned:

1994: Our *Nature* paper on alpine plant species changes

focused the attention on the great monitoring potential of mountain biota;

1997: The broad response from the scientific community to be willing to join the international alpine species monitoring initiative;

2001: Successful application of the pilot project GLORIA-Europe;

2004: GLORIA field manual published as official publication of the European Commission;

2012: Results of pilot project GLORIA-Europe of GLORIA provided the first comparison of sites for an entire continent. A reviewer stated “by far the best data set”;

In general I am proud that GLORIA has stimulated alpine plant ecology studies tremendously; GLORIA has successfully established sites in more than 100 target regions; and the GLORIA program has never experienced internal conflicts.

Connie: Have there been any especially surprising or unexpected results from the GLORIA network?

Georg: Uncertainties are unavoidable in climate change research, its effect on alpine biota in particular. In fact, the only certainty is the unexpected. To list a few:

- Mediterranean mountains are also affected by dry summers; species richness has not increased;
- Even under strong warming $> 3^{\circ}\text{C}$ micro-refugia might allow local populations to survive; at Master Station “Schrankogel” typical nival plants were found in a cold air drainage at tree line;
- Infilling effects have to be distinguished from migration effects; there are many alpine species with a ruderal strategy;
- Clonality is a common character to quite a number of species: for me the *Carex curvula* story, occupying large areas in the Alps, is one of the most exciting examples of how careful observations revealed important knowledge: *C. curvula* forms clones that grow like fairy rings, which later disintegrate. Swiss colleagues, applying DNA fingerprinting, provided evidence that genets of *C. curvula* germinated 5000 years ago, while some clones several 100 years old might occur as dwarf shrubs;
- Even the early ecologists recognised several obvious mountain zones and ecotones, although upper treeline is the most striking. The alpine/nival ecotone, however, has been either neglected or not studied in detail. The project “Mountain Limits” provided evidence that this ecotone is in fact at the elevation where summer snow is most variable and coincides with highest change (beta-diversity) in floristic composition.



Hari Responds:

Connie: You've also worked with the GLORIA Program since its early days as Science Chair and now take over as Program Director. What do you consider the key strengths of GLORIA as you go forward in the next decade?

Hari: In the late 20th century, when mountains became a focus

of global attention and the climate change debate and research intensified, the urgent demand for an international observation system for the natural or semi-natural biosphere at its cold edges was recognized. For a long time, such programs were already in place for meteorologists, climatologists, glaciologists, but lacking for standardised measurements of biodiversity patterns.

To fill this gap, GLORIA emerged as an Austrian initiative, joined by concerned ecologists from four continents at its beginning around the turn of the millennium. A European Union project provided the 'critical mass' for a concerted start with monitoring sites in 18 mountain regions across the continent, shortly after followed by site establishments in North America, and to a smaller extent also in South America and Australasia. A key difficulty in this implementation phase was to deal with increasing short-duration funding possibilities – kind of swimming against the mainstream flow of rapid project cycles with a real long-term approach, where actual change detection would only commence after a period longer than most research projects. A strong emphasis on comparability, simplicity, and economy, as well as the engagement of an increasing number of biologists, made it possible to overcome this ever-present difficulty: The GLORIA programme now comprises a network of observation sites in 120 mountain regions, distributed over six continents.

Hence, the key strengths are now in place:

- (1) A world-wide setting of standardised permanent plots arranged along the fundamental climatic gradients in elevation, latitude, and longitude across the plant's major biomes.
- (2) The data sets include all vascular plant species occurring in each plot. Even if some species remain persistent with hardly any visible change over decades, shifts in the composition of all players can be highly indicative even over shorter periods of just a few years.
- (3) Data analyses that included the first resurvey cycle confirmed this assumption by showing unprecedented results about wide-spread thermophilisation of alpine plant communities and even decreasing species numbers in summer-arid southern Europe within a period of less than a decade. Within the next decade, many more sites will yield repeat data sets and many even a third or a fourth monitoring cycle, having the potential to discern trends in -- and the velocity of changes in -- species composition. Second, the upcoming years should allow for inter-continent comparisons such as between North America and Europe. Studies of fundamental plant diversity patterns in cold environments from tropical to subarctic biomes should be possible for the first time on the basis of standard permanent plots.

Not least, of course, the international GLORIA coordination is now institutionally re-established after a difficult re-structuring process, affiliated now to two strong Austrian research institutions, the Austrian Academy of Sciences / Institute for Interdisciplinary Mountain Research as well as the University of Natural Resources and Life Sciences / Center for Global Change and Sustainability. With my young team colleagues – Manuela, Andrea, Sophie, Bine, Armin – we are doing our best to tackle the day-by-day work and to proceed with upcoming challenges. At this point, I also wish to address Michael Gottfried's commitment to GLORIA, who has been a fundamental pillar for developing and establishing the programme – hopefully he can find a way to recover from his sudden illness.

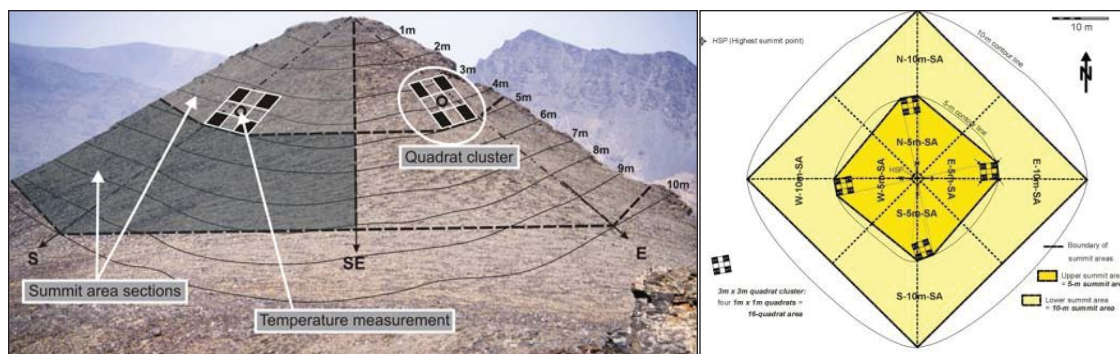


Figure 3. GLORIA side-view of summit design (left) and air-view (right).



Alpine gold (*Hulsea algida*), Sweetwater Mtns, CA. Photo: C. Millar

Connie: Do you have plans for expanding or modifying any aspects of the Program, or using the data gathered by Target Regions in new ways?

Hari: The further expansion of the site-based network is still ongoing at an unbroken pace, and is certainly highly appreciated in order to cover still underrepresented mountain systems such as in central Asia, Africa, and on oceanic islands and, especially, to enhance statistical significance of regional studies.

The standard protocol was only slightly modified within GLORIA's first decade. In order to keep it operable on a global level, the basic procedure must be simple and rapid enough to be manageable even in remote mountain regions. Therefore, and after a broad discussion, the most time consuming parts, such as very detailed frequency counting, were set to an optional level, but this step was not completely removed, and more rapid and calculable pointing methods were introduced in addition to the existing visual cover estimation method.

GLORIA data are "pluripotent" enough to be not only usable for detecting changes induced by climate warming or climatic variability, but also for those influenced or caused by land-use impacts such as grazing (which may have changed in varied directions such as abandonment or overgrazing in different parts of the world, at least at some of GLORIA's lower sites) or through atmospheric nitrogen deposition, where critical loads strong enough to alter plant growth and composition may be reached in some regions.

In this context, identification of suitable functional plant traits, which partly could be obtained from literature sources or existing data bases and partly have to be measured in the field

will be a promising but challenging task. Further, additional data on species' altitudinal and overall distribution ranges are to be collected in order to explain current and changing patterns of species composition. In addition to traits for ecosystem functioning, species' distribution patterns are expected to hold some of the keys for interpretation of changes; e.g. species with a continental-arid origin, such as *Kobresia myosuroides*, which in the Alps also occurs at windswept sites, may be better adapted to decreasing water supply than arctic-alpine ones. On a global level, it will be interesting to determine if species of similar biomes (such as Mediterranean-type, interior steppe-type, tropical humid, arid...), but distant from each other, share similar traits, and if there are fundamental trait-differences with contrasting-climate biomes.

Within the past years, a number of additional activities are arising out of the global GLORIA network, partly applied in so-called GLORIA master sites, where more extensive research facilities are available, but also as extension in standard multi-summit study regions. Such activities include downslope transects in short regular elevation intervals to identify regional altitudinal ranges, different monitoring approaches for various animal groups, and even socio-economic and cultural aspects relevant in GLORIA regions.

Connie: What types of outreach efforts have been most effective in communicating the results and implications from the GLORIA network?

Hari: Outreach to policy makers and the public certainly is a core concern of the GLORIA programme. Although much of GLORIA's work is essentially basic research, it was designed as an indicator system of critical impacts on biodiversity patterns caused by large-scale human-induced climatic and environmental phenomena. GLORIA should, therefore, also function as an early warning system for critical shifts in species composition. This, in turn, should help in designing well-targeted conservation strategies.



Resurvey on White Mtn GLORIA site, 2009. Photo: S. Sady/TahoeLight



Georg (far right) and Hari (2nd from left) join Connie Millar (far left) and others for a GLORIA reconnaissance trip in the Sierra Nevada, 2004. Photo: D. Dulen

In the search for biodiversity/climate change indicators, the European Environment Agency (EEA) could find one for migratory breeding birds and one for butterflies, both based on existing extensive data sets. For plants no such indicator was available on a Europe-wide scale. Therefore the EEA was contacting the GLORIA coordination to fill this gap. Through the 2012-publications in *Nature Climate Change* and in *Science*, the foundations of the requested indicator are established.

GLORIA, with its unique network, programme and role, is well in the “display window” and, thus, rather often in the public media. GLORIA’s website, where a number of updates and improvements are pending, certainly is crucial for fostering outreach. High ranked publications of the past year gave a boost in media presence as well as did the election of Georg Grabherr for the “Austrian Scientist of the Year 2012”, awarded by Austria’s education and science journalists.

Connie: What do you see as the most important challenges from the research perspective within the GLORIA framework?

Hari: Well, this is a mix of further structural improvements in data compilation and exchange targeting cross-continental comparisons. I guess that a North American multi-site paper could come up in near future, and upon that a North America-Europe paper would be desirable. The mountain research meeting planned for Reno, NV in July, 2014 could be a good opportunity for discussing and defining procedures.

Moreover, comparisons of similar biomes such as the European Mediterranean and the Californian environments could be

inspiring. In this context we are now planning additional measurements of soil-water potential at the Mediterranean sites, and to compare with the situation in the temperate Alps. Decreasing water availability in Europe’s southern regions could be a key factor for the observed decline in species numbers.

Other important tasks were already mentioned above, such as using sensitive plant functional traits and distributional “traits”, where the challenge is to develop effective concepts and protocols, and to identify data gaps and how to fill them. The work with plant functional traits continues to boom on the international research landscape, where hardly anybody else has such a large data set from real permanent plots.

The most immediate task to be tackled is to get the new version of the GLORIA field manual in place – a priority that is already within reach. This is certainly essential and by all the widening of the scope and possibilities to answer new research questions, it is important to not lose the focus of the unique core role of GLORIA. Further a study on observer variability in cover estimation and species detection, based on parallel data sets from test sites from two European regions, which is in an advanced analysis stage, will be an important task. Before running the third survey on the GLORIA master site “Schränkogel” in 2014 und Europe-wide surveys in 2015, further analyses with existing European data sets are planned including the use of plant functional traits – in a first step with emphasis on the Alps, where many trait data are available. In the topical Andes, data from GLORIA sites of six countries are now in a very promising, multi-site analysis procedure, which also uses functional traits.



Alpine gentian (*Gentiana newberryi*), Sierra Nevada, CA. Photo: C: Millar

When I'm sometimes asked, 'What use are all these data and future anticipated results for such a marginal part of the biosphere as the alpine zone', I could say that this is (1) the only globally distributed biome type that is not strongly disturbed by direct human activities; (2) this diverse natural part of the biosphere, however, is now also affected throughout by human-induced global climate change; (3) mountain habitats and biota are the best natural lab to study the ecological implications of climate change; (4) the world-wide expanding human influence will pose additional pressure on alpine biota; (5) I'm still convinced that a large part of the global human society (if not a majority) would regret a further shrinking of the natural biosphere and would consider its cautious use an important challenge; and (6) To be able to respond in a proper way, and to effectively counter further degradation and widespread homogenization of species communities, long-term observation appears to me indispensable.

Rather, I wonder why nobody did commence earlier with such a site-based monitoring network – as the ecological climate impact discussion started as early as in the 1980s, as Georg was mentioning. And why such efforts, being anyhow not really expensive, still live financially in the shadow. Anyway, this is ever more a motivation to go forward and to stimulate others to join in.

Georg and Hari Summarize:

Connie: What lessons could you both share with the CIRMOUNT community about how to effectively launch and maintain a successful long-term global monitoring program such as GLORIA?

Georg and Hari: CIRMOUNT, emerging contemporaneously with GLORIA, both have a rather similar focus, namely on climate change and on mountains. As such, they are a wonderful example of programs complementing each other in a flexible cooperation. CIRMOUNT, with the strength of an interdisciplinary community with expertise ranging from physical to biological research fields, focuses on the extensive mountain world of western North America; GLORIA is more disciplinary focused on biodiversity, but at global scale. CIRMOUNT was essential for GLORIA to get a foothold in North America, and continues to be highly important for increasing the number of sites, keeping them in operation, and, moreover, to contribute with great experience in developing additional activities related to GLORIA sites. GLORIA, in turn, links together the global community of mountain ecologists and botanists.

The upcoming major meeting on mountain observation activities in Reno, NV, in July 2014 (see page 32), will be a very good opportunity to further expand this already fruitful collaboration.

Find publications mentioned in this interview on the International GLORIA website: www.gloria.ac.at/



Sierra Nevada GLORIA Target Region. Photo: C. Millar

Voices in the Wind

In this section of Mountain Views Newsletter, we query members of the CIRMOUNT community for their perspective on a question of current interest. Given the heightened need for active implementation of climate adaptation projects, I asked mountain scientists who are leaders in this subject to comment on the following question.

– Editor

What climate-adaptation activities or projects do you consider most urgent to be addressed in western North American mountain ecosystems in the next five years?

Molly Cross (with daughter, Willa), Climate Change Adaptation Coordinator, Wildlife Conservation Society, Bozeman, MT

As we lose critical storage of water in mountain snowpacks, I think it is essential that we look for others ways to store water in mountain ecosystems. The urgency comes from the inevitable strain that declining water availability will have on already tenuous relationships between various water users, including both human and natural systems. Can we increase the 'sponge effect' of mountain ecosystems to at least partially compensate for the loss of snowpack storage? In what ways can we adjust our management of forests, riparian areas, wetlands and meadows to maximize their water storage potential? If we can demonstrate effective ways to increase water storage in natural ecosystems, with benefits to downstream users (both natural and human systems), we may be able to create a broader constituency for natural mountain ecosystems. There are many efforts across the West (I'm familiar with several in the Sierra Nevada and northern U.S. Rockies) to look at meadow, wetland and riparian restoration projects through the lens of water storage under altered climate conditions; perhaps great value can come of connecting these disparate projects and formalizing our learning from them. Questions abound about whether ecosystem storage of water can compensate in any significant way for the loss of mountain snowpacks, whether management of ecosystems for water storage is good for other values (e.g., wildlife habitat, recreation), and whether such storage will lead to notable benefits downstream. The sooner we tackle these questions the better for getting out in front of the water wars that will inevitably be escalated by climate change across the West.



Deanna Dulen, Superintendent, Devils Postpile National Monument, Mammoth Lakes, CA

Devils Postpile National Monument is at the center of the ecological richness of mountains, rivers, and meadows within the Middle Fork of the San Joaquin River Canyon in the Sierra Nevada. Soda Springs Meadow's flora and fauna provide the interconnecting threads of nourishment to a symphony of wildlife that nest, den, feed, and/or migrate through the meadow. Yet throughout the Sierra Nevada, meadows are impacted by many stressors that compromise their ecological integrity and hydrologic functions. Some of these stressors can be mitigated and others may respond to adaptation strategies. That is why, I believe, that focused efforts to conserve specific meadows throughout mountain regions, and Soda Springs Meadow in particular, as meadow refugia must be a priority for this and future managers of the Sierra Nevada.



Gregg Garfin, Assistant Professor and Assistant Extension Specialist in Climate Science, Policy, and Natural Resources; Deputy Director for Science Translation and Outreach, University of Arizona, Tucson, AZ



Connections. Linkages. Integration. The most important adaptation priority for mountain regions in North America is well integrated planning that links headwaters and fragile mountain environments with downstream water users, in the most comprehensive manner possible. There is a tendency for society to break down issues by discipline or sector, in order to simplify issues, or by habit, narrow-mindedness, or laziness. In

my opinion, what is lacking from many adaptation discussions is dedication to a process that integrates many inter-related concerns. We need to convene planning initiatives that examine vulnerabilities, potential consequences, and strategies that take into account all ecosystems, including managed systems (e.g., agriculture), and which make explicit linkages between downstream and upstream water, recreation, and resource extraction activities. This is a daunting, but necessary, task, and one that can develop thoughtful adaptation through transparent communication of the assumptions made by parties representing various sectors. Multi-sector processes occasionally foster unholy alliances and odd bedfellow partnerships, which are much needed to remove the artificial barriers that develop when discussions are stovepiped. By not making these connections, our society risks a game of winners, losers, resentments, environmental degradation, maladaptive strategies, and, ultimately, less economic prosperity.

Jessica Halofsky, Research Ecologist in Climate Adaptation, University of Washington, Seattle, WA



I think thinning in forest ecosystems that historically experienced relatively frequent low- and mixed-severity fires is an urgent need in western North America. In addition to decreasing likelihood of stand-replacing wildfire, there is increasing evidence that thinning in these forest types can increase resilience to climate change

by moderating tree competition, and increasing residual tree access to light and moisture, thereby reducing sensitivity to climate stressors.

Koren Nydick (with son, Owen), Science Coordinator/ Ecologist, Sequoia & Kings Canyon National Parks, Three Rivers, CA

I think that there is a plethora of ways that scientists, educators, managers, and policy makers can advance climate change adaptation. Here are a few that are particularly important in my opinion:

In terms of long-term monitoring, we should focus on measuring the most critical metrics and developing cost-effective methods that are designed to be implemented across jurisdictional boundaries. Scientists should consider partnering with educators to incorporate volunteers when methods allow.

In terms of on-the-ground climate adaptation, restoring fire (and/



or mechanical fuel reduction) to fire-adapted ecosystems is a top priority for increasing resilience in the face of climate change-driven drought, insect infestations, pathogens, and large-scale high severity fire. Fire and fuels management is a powerful tool that benefits large landscapes, including both terrestrial and aquatic components and human safety/property. There are many road blocks, however, so the challenge is really one of socio-economics, policy, and how people deal with short- versus long-term risk.

In terms of applying scientific information to help us make climate adaptation decisions, we should develop methods for combining this science with human values and management feasibility. Vulnerability to climate change in and of itself does not make a decision. Should management effort be prioritized for species, ecosystems, or places that are least vulnerable because they represent the best chance of long-term persistence, or should we focus on those that are at most risk? The more this process is made transparent and involves partnerships and stakeholder dialogue, the more likely we are to come to decisions that are supported by different constituents.

Another urgent issue is what to do following extreme events, such as the recent Rim Fire in California or the floods in Colorado, that are becoming (and are predicted to become) more common as a result of climatic change. We should be learning from each event that occurs and planning for future events by mitigating unacceptable risks and determining ahead of time the criteria we will use for making decisions about ecosystem restoration or transformation.

Lastly, I think we should identify which species are the highest priority for assisted migration and develop contingency plans for doing so. Controlled pilot tests should be carried out to develop methods and refine the selection criteria before the assisted migration becomes a last chance effort.

Steve Jackson, Director, DOI Southwest Climate Science Center, Tucson, AZ

Resources for climate-change adaptation are limited, and that's unlikely to change. We need to use those resources judiciously and strategically. There's a lot of adaptive capacity in the species and ecosystems of the region. Certainly one urgent need is to inventory and assess that capacity, so that we can leverage natural adaptive capacities most effectively and target our interventions where they'll make a real difference.



Dave Peterson, Research Scientist, USDA Forest Service, Pacific Northwest Research Station, Seattle, WA

As Wallace Stegner famously wrote, “aridity is the key to understanding the history and culture of the American West.” Addressing how lower snowpacks, lower water supply, and increasingly variable stream hydrographs (more frequent floods AND lower summer flows) will affect local communities and regional economies is central. Water has been over-allocated in many areas, so water distribution systems are already stressed, and conflicts will emerge among different users -- agriculture, municipalities, hydroelectric power, fisheries, recreation. A relatively small change can push this system beyond any hope of sustainability.



The most important adaptation approach will be for water users to develop enduring partnerships to identify potential effects of climate change on water resources and options to reduce negative outcomes. The sooner these partnerships are developed, the more options will be available before “crises” occur. Engineers are already developing creative approaches in anticipation of altered hydrology — risk assessments across large landscapes, new standards for roads and culverts that will tolerate increased flows, prioritization of roads for decommissioning, water passages that are fish friendly. It has been enlightening to see how quickly engineers “get it” and are able to move forward with solutions. If other scientific and management disciplines can emulate this proactive approach, we will improve our chances of successful adaptation in mountain ecosystems.

Nate Stephenson, Research Ecologist, USGS, Sequoia and Kings Canyon Field Station, Three Rivers, CA

Planning for “the Big One.” By that I mean having a plan in place for how to respond to a severe, widespread, abrupt change, like the effects of an unusually extensive and severe wildfire. Such events are likely to become more frequent in a changing climate. Our window of opportunity to meaningfully respond to such changes – whether by strategically managing erosion or re-planting with species adapted to a warmer climate – may only last a few years. But the usual planning and compliance horizon for land-management agencies can span many years,



so we can’t afford to wait until the Big One happens and only then begin to plan our response. If we’ve gone through planning and compliance ahead of time – anticipating that there’s a good chance that at some point we’ll see sudden, severe changes on any particular piece of ground – we’ll be in a much better position to respond in a thoughtful, adaptive way.

Jim Thorne, Research Ecologist, Information Center for the Environment, Department of Environmental Science and Policy, University of California, Davis, CA

Resource managers are typically tasked with managing conditions for specific areas on the landscape. Some of the things they need to know, therefore, are tied to those mandates, and the development of practice and policy that allows for the implementation of test actions, and their evaluation is one need for climate adaptation. The evaluation component of this comment is meant to



take advantage of the time-frame over which we have projections of what climate change is going to do, i.e. that it is happening, but that we will not immediately arrive as the conditions of 2100, even if modeling gives us some idea of what those conditions may be. So, adaptive management will need to be even more a part of everyday activities.

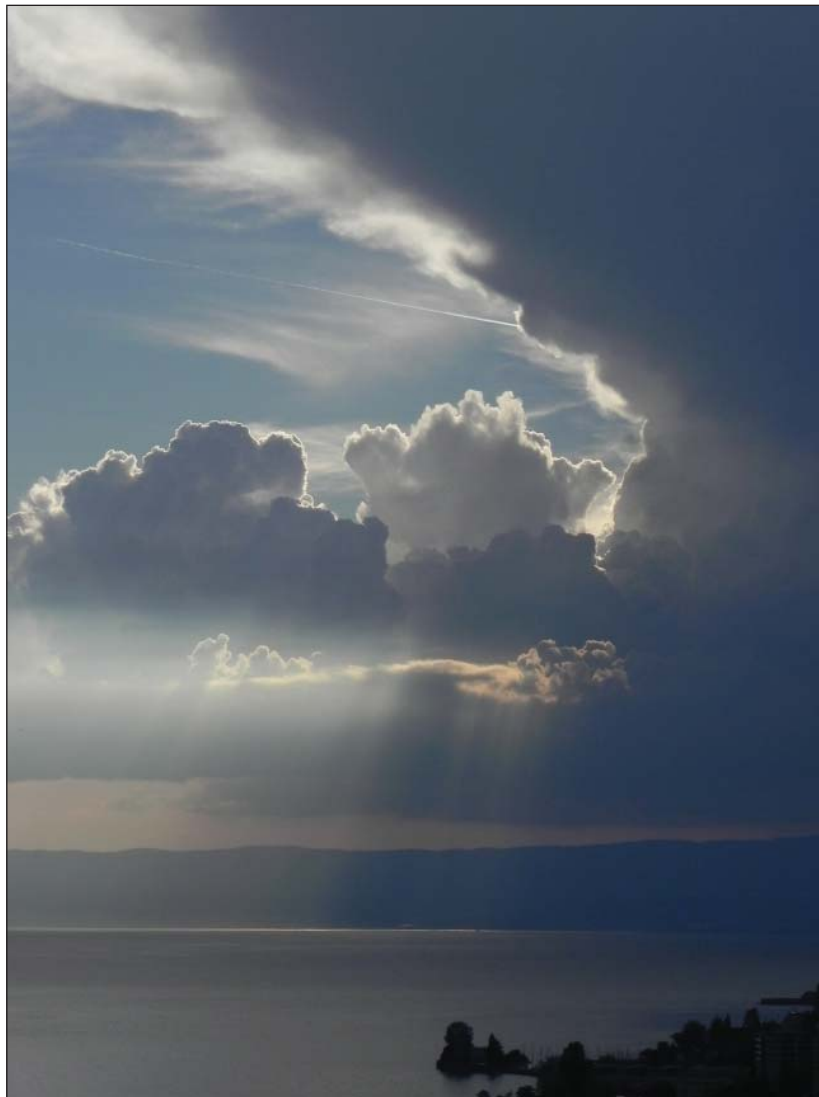
However, many of the things that land managers need to address are processes that are happening across wider regions. Therefore more regional assessments are needed, and coordination between managers (and the public) is needed to develop strategies for management that can be applied locally, but are globally (or at least regionally) relevant. Examples of these considerations include things that are already in discussion among western conservation and ecosystem circles- connectivity and water. But new concerns are also arising, including larger fires, disease outbreaks, regional die-backs or expansion of species, and more frequent droughts, floods, and temperature extremes. Identifying whether there are strategies that can emerge for regional approaches to these types of challenges is needed.

A recent example from the southern Sierra is an initiative for joint fire & research meetings that include national park and national forest representatives, to use workshops and even a gaming approach to try and discern if there are better applications for limited proactive fire management on the landscape, given mapped projections of increased climate stress and fire risk to a landscape of varying vegetation types. Similarly, a project I’m working on is to locally calibrate and present hydrologic response to projected climate change for management on National Wildlife

Refuges. The idea is to help local refuge staff get a better idea of how conditions may change, which could allow them to consider how they might need to change the management of water diversions that many refuges conduct to promote water fowl populations. These types of projects will also likely need to develop public-private partnerships to address emerging concerns across patchwork landscapes.

A number of forested regions in the western US are starting to engage with carbon sequestration concepts. In order for these to be effective, understanding of fire risks, and explicit inclusion of management to address those risks is needed.

Finally, if as projected, snowpacks continue to diminish, then much more work is needed to figure out how to retain moisture on the landscape, both of ecological objectives and as ways to better promote ground water recharge that can help supply human populations.



Clouds over Lake Geneva, Switzerland. Photo: G. Greenwood

Update on Mountain Research Initiative Activities

Building a Network of Mountain Observers

Greg Greenwood

Mountain Research Initiative, Bern, Switzerland

Enhanced observations of mountain regions have been a central concern for MRI from the beginning. While a more comprehensive international system of mountain social and ecological observations is needed, there is no single entity with the authority to organize it or the budget to fund it. Thus it must be built up from existing regional networks and sites. And the best way to do that is to convene researchers from those networks and sites to exchange ideas, see what other networks offer, develop common programs, assess priority locations, and develop creative financing options. To that end, MRI and University of Nevada Reno are organizing *A Global Fair and Workshop on Long Term Observatories of Mountain Social-Ecological Systems*, scheduled for 16–19 July 2014 in Reno, NV, USA. See: <http://mri.scnatweb.ch/fair-and-workshop-on-mountain-observatories/home>

The subtitle “Fair and Workshop” signals a dual approach, with the Fair promoting open-ended interaction and the Workshop promoting more traditional focused presentations and discussion. The Fair is planned as an elaborate poster session, a marketplace in which researchers and managers of different observing sites and networks present Expositions of their goals, sites and methods, so that other researchers who may be interested in expanding their capabilities can learn what is available. The Fair will also facilitate Side Meetings where people can pursue more focused discussions or even negotiate agreements.

The Workshop component will provide an opportunity for participants to address themes or issues that go beyond their particular site. It will be composed of *Sessions*, in which participants present papers to an audience much as they would at a scientific meeting, and *Ateliers* (meaning a “shop” or “studio”), in which participants engage with others to discuss a particular topic.

To date, the Fair and Workshop has over 60 Sponsors from around the world. A Second Call is now available, asking for submissions of Expositions, Sessions, Presentations and Ateliers. This event seems to have some traction within the community, and should the response be what we hope, MRI may create subsequent editions in Europe, Asia and elsewhere in future years.

Understanding Climate Warming at High Elevations

The goal of the Global Campaign on Accelerated Climate Warming at High Elevations, now to be rechristened as the Global Campaign on Elevation Dependent Warming (EDW), is to assess whether—and if so, where, to what extent, and why—mountains and other high-elevation regions are warming more rapidly than other parts of the planet.

The working hypothesis is that during this period the temporal rate of change of temperature has been greater at higher elevations than at adjacent lower elevations. The existence of elevational dependent warming has not been shown convincingly around the world (Rangwala and Miller 2012). But it matters a great deal to downstream communities whether it is real.

This initiative is a campaign, not an event or a review paper, as we fully expected that definitive answers to the underlying questions will require the effort of many researchers around the world for up to a decade. This campaign will involve a review of existing science but will certainly also require the collection of new data, as it is the paucity of high-elevation station data that principally precludes definitive answers.



Climate monitoring station at Barcroft, White Mtns, CA, 3800 m.
Photo: C. Millar

The EDW campaign is the demand-side counterpart to the supply-side observatory Fair and Workshop. While the Fair and Workshop will determine what data we can get (and what questions we can answer) by coordinating existing efforts, the EDW campaign will specify the kind of observation network we need if we wish to answer important questions on accelerated warming.

Generating a successful campaign will require not just a scientific proposal and a funding plan but also a committed network of champions willing to develop and then pursue the effort. While the Fair and Workshop has a long list of sponsors, MRI has enlisted six researchers (Nick Pepin, John All, Michel Baraer, Wolfgang Schöner, Imtiaz Rangwala, Jim Miller), working under co-chairs Ray Bradley of the University of Massachusetts and Tandong Yao of the Institute for Tibetan Plateau Research, to frame a workshop that will develop the proposal and funding plan. The workshop is planned for 23-25 April 2014 just before the European Geophysical Union meeting in Vienna.

The workshop will focus on several key questions:

First, why would we expect enhanced warming at high elevations and where would we expect the mechanisms responsible to be most manifest? Several mechanisms have been proposed as either contributing to or diminishing EDW. This session will assess the state of knowledge related to these mechanisms and identify the ideal locations and measurements needed to confirm their relevance.

Second, the workshop will examine the evidence for accelerated warming at higher elevations: how researchers have conceptualized the question, the specific hypotheses they have examined and the data used. It will identify where we have high certainty in our answers as well as the major gaps in measurements.

A third session will explore how we can improve existing datasets, i.e., on all the steps that could be taken to create a global dataset that fills the gap noted in our attempts to evaluate the proposed mechanisms. While station data are an obvious target, it will be important to assess reanalysis data as well as other sources of data, especially remote sensing.

The workshop will then focus on the specification of new observational efforts needed to evaluate comprehensively the hypotheses related to accelerate warming. A central premise of this session is that regardless of the success in the creation of a global dataset of existing observations, the commonly acknowledged paucity of observations at high elevations will

require a concerted new observational campaign in order to evaluate the various hypotheses. Where, how, and for how long are key parameters that must be set for the new observational campaign. Finally and perhaps most crucial, the workshop will determine the steps needed to implement the plans related to new datasets and new observations.



Alpine plateau of the Central Sierra Nevada rises abruptly from adjacent basins to elevations over 4000 m. Photo: C. Millar

Understanding Agency and Governance in Mountain Regions

The third MRI effort focuses on a global study of agency and governance in mountain regions. As much as the community of mountain researchers agrees that human dimensions are important, a rigorous scientific approach to studying not just human ecology (as if our species were just another species of wildlife) but also the cognitive and political dimensions of human behavior in mountains has been conspicuous in its absence (Björnson Gurung et al. 2012).

The notion of "coupled human-natural systems" has been part of MRI's lexicon through its close association with the Global Land Project. The GLP Science Plan articulates a reciprocal relationship between ecological and social systems that creates the "land system" which is itself embedded within the larger Earth system (Fig. 1).

The science as it pertains to the right side, in which management impinges on ecosystems, alters their structure and function, and thus sets the nature and amount of ecosystems service flowing back to the social system, can now be roughly described with mechanistic models of ecosystems. There is still much to do, but the general form of an answer has emerged in these models

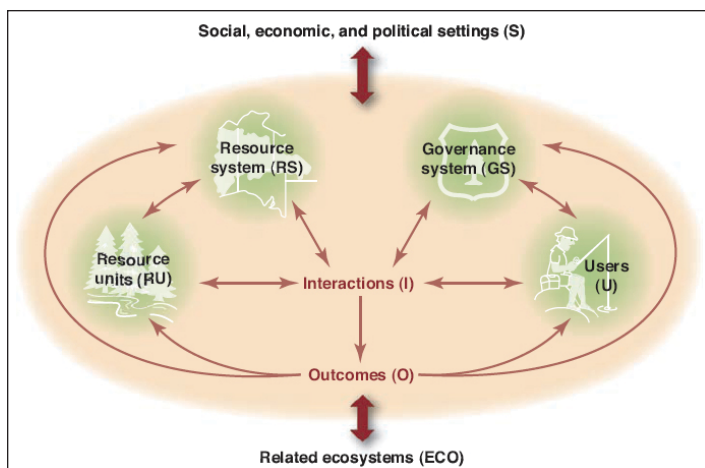


Figure 1. The Earth and Land System per GLP (2005).

and articulates the wide range of relevant notions - radiation and photosynthesis modulated by water, cycles of elements and compounds, trophic levels, biotic community organization, etc. These elements are not all of what's inside the ecological system - that is nearly infinite - but rather that which we need to understand how inputs - management, climate - lead to outputs - ecosystem services.

The question naturally arises as to what's inside the social system circle. The full contents are also nearly infinite, and thus we restrict ourselves to that which transforms the inputs - ecosystem services, global drivers - into outputs - management.

Note that while the currencies in the ecological system are matter and energy, the currencies in the social system are not. Exactly what they are is part of the discussion, but at the outset they seem to be more related to information flow and subsequent actions, that is, how decisions are made. Thus while we need a model of the social system, just as we need a model of the ecological system, we should not assume that the form of the former will have anything to do with the form of the latter.

A full exploration of how decisions are made, i.e. the governance of mountain systems - how to characterize them, how they differ across cultures, how they will change - goes beyond the scope of the single Synthesis Workshops that MRI has organized in the past. Nor can we say with certainty exactly how to go about describing governance. What MRI is doing is convening sessions and workshops that we hope will attract a quorum of social scientists and from which we hope will emerge some strong directions.

The MRI has sponsored two sessions at the *Global Land Project's Open Science Meeting* in Berlin on 19–21 March 2014. The first is a Round-Table discussion, co-chaired with Jörg Balsiger (University of Geneva) and Jayne Glass (University of Highlands and Islands) on the role of governance in adaptation to global change in mountain regions. This session will begin with the general concern of all descriptive governance studies - what are the institutions that govern behavior and lead, among other things, to the management of land resources - but will then proceed to the more specific questions of how the highly dynamic nature of the physical environment, the historical diversity of mountain cultures, and the on-going modernization of these regions affect governance arrangements.

The MRI is also co-chairing with Thomas Kohler (University of Bern) a scientific session focusing on coupled human-natural system models for the assessment of the dynamics and resilience of mountain socio-ecological systems. Coupled human-natural system models provide a rigorous framework by which to express the multiple spatial and temporal scales of the drivers, their repercussions through the system and the resultants feedbacks. Their use permits the quantitative assessment of impacts and responses. In addition and in the current context, such models often support a detailed and quantitative assessment of resource governance in mountain regions. As with the services they provide, the governance of mountain regions is frequently multi-level, with authority dispersed across space and leading to novel dynamics itself. Coupled models thus provide a means for assessing likely future trajectories, and, more globally, the resilience of mountains socio-ecological systems to perturbations.

The MRI has also taken a lead in proposing a governance theme for the Dennis Machida session at the *MtnClim 2014 Conference* in Midway, UT, USA on 15–18 September 2014. The objective here is to show to the generally biophysically-trained but nonetheless socially committed *MtnClim* audience how social science conceives of that great black box of "social systems", and how knowledge of social systems can be useful.

We have proposed to start with Ostrom's Social-Ecological System approach (Fig. 2) as a point of departure, and later as a foil for other methodological approaches. The session will then portray empirical work that can illuminate the strengths and weakness of theory. The session will conclude with an open discussion lead by Gregg Garfin (University of Arizona) to explore how holders of these two different intellectual traditions (of earth system science and of human system science) could jointly imagine some kind of synthesis work.

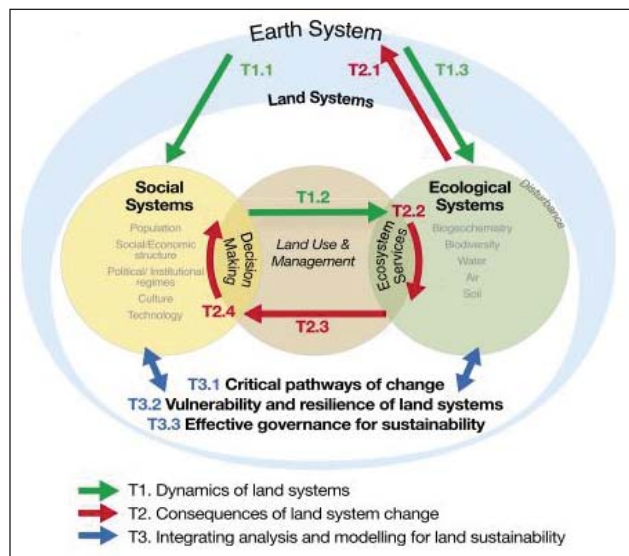


Figure 2. Elinor Ostrom's Framework for Social-Ecological Systems (Ostrom 2009)

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For more information on the Mountain Research Initiative, contact Greg Greenwood at greg.greenwood@giub.unibe.ch or visit the MRI website: <http://mri.scnatweb.ch>



Stockhorn, from Walalp, Switzerland. Photo: T. Angeli

What Can Climate Services Learn From e-Commerce?

Nina Oakley

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In an office in Carson City, Nevada, a water resource manager squints at a computer screen, pondering the options in front of her in a quest to find the appropriate precipitation data for her current project. "Download raw data? Use data tools? I'm not sure what I need!" She clicks around a few more times, and the results don't quite meet what she was expecting. Frustrated, she looks up the contact information for the site and sends an email describing her project goal and asking where to find the appropriate data.

I receive her email at the Western Regional Climate Center in Reno, Nevada and wonder how much time she spent looking for the data before emailing. What complicated her search? The structure of the site? Unfamiliarity with climate data terms? What can we do in climate services to make it easier for people to find what they are looking for? Beyond that, can we act as an "e-Climony" to match users with a dataset compatible with their application based on a "scientific approach"? I began looking for answers in e-commerce. Much effort has been taken to make sure it is easy and intuitive to find the product you are looking for and purchase it on Amazon or create an account and watch a movie on Netflix. Perhaps the interfaces used on commercial sites have lessons to offer climate services.

Traveling down this path led me to the field of usability and user experience (UX). The International Standards Organization (1998) defines usability as, "The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use." Dumas and Redish (1999) outline usability with four points: (1) Usability means focusing on users; (2) people use products to be productive; (3) users are busy people trying to accomplish tasks; and (4) users decide whether a product is easy to use. Providing a good user experience becomes necessary since content on the web is bountiful, and users can often find what they are looking for elsewhere if they become frustrated with your site. Worse, if you exhaust users' "goodwill" towards your site by making it difficult to find what they are looking for, they may not be eager to use it in the future or think less of your organization (Krug, 2005). Generally, a user will make the choice to stay on a site or leave within the first 10-20 seconds (Fig. 1). This is not true across all websites and all users but a starting point for thinking about the importance of engaging users in a short amount of time.

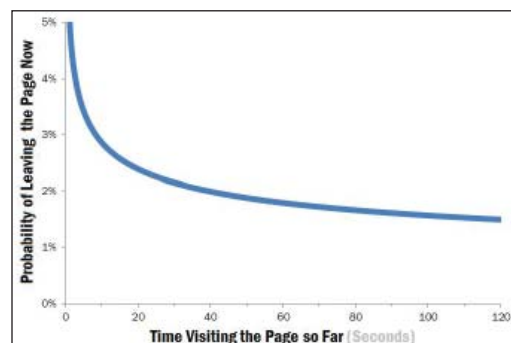


Figure 1. Likelihood of leaving a web page on a visit. Image source: Nielsen Norman Group <http://www.nngroup.com/articles/how-long-do-users-stay-on-web-pages/>

With the ever-growing number of websites providing weather and climate data, it is clear one has to take a thoughtful approach in the design of a site to cultivate user satisfaction as well as build user loyalty. Usability consultants have found that user loyalty is extremely valuable in economic terms, with loyal users tending to spend considerably more money on a site than a first time user (Nielsen, 1997). For data providers that are grant-funded, defining a loyal user base helps to show the relevance of your site and aids in securing financial support.

To learn about usability and UX, I started by reading an excellent book, "Don't Make Me Think: A Common Sense Approach to Web Usability" (Krug, 2005), which outlines the basic "do's and don'ts" as well as justifications of usable design. Looking for further insights, I attended Usability Week, a weeklong workshop

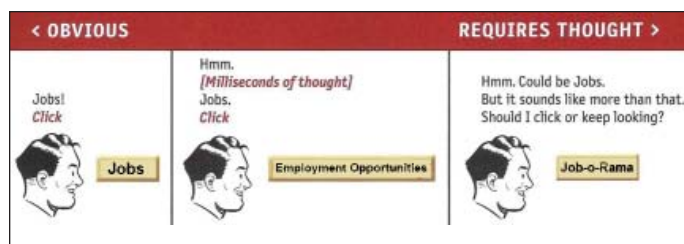


Figure 2: Use terms that users will recognize to reduce cognitive load. Image excerpted from Don't Make Me Think: A Common Sense Approach to Web Usability, Second Edition by Stephen Krug. Copyright © 2006. Used with permission of Pearson Education, Inc. and New Riders.

addressing various aspects of usability for web pages, apps, and intranets (NNG, 2013). My fellow attendees hailed from successful enterprises such as Google, CISCO, ESRI, TiVo and Fandango, to name a few, so I felt I was at the right place to learn about usability. From the conference and reading material, much of the material applies to good web design in general, though several principles stood out as essential for providing climate services (Fig. 2):

- Limit options at each step of a task to reduce cognitive load.
- The user may have a different construct for certain words than the scientist/programmer designing the site.
- Users are most likely to try and “muddle through” rather than read instructions.
- Follow pre-existing web standards, such as search bar in upper right of page and clearly defined buttons to click on.
- Develop and maintain user loyalty.
- Test the site early and often with target users!

Exactly how to address these principles in the provision of climate data is the challenge we face. The organization of climate data is much more complex than shoes or books, and the implications of misusing climate data can be far more severe than accidentally ordering the wrong shoe color or not finding the link to watch your favorite show. As providers of climate data, we have a daunting task of figuring out how to present complex information in a user-friendly manner. Additionally, there are currently no widely-followed standards for accessing climate data. This gap provides an opportunity to develop standards, though they must be well thought out and tested as well as adapted by other climate service providers. Standards clearly exist for purchasing items in an online store. There is generally the use of a shopping cart, and the forms used to complete an order follow a similar sequence and use comparable language across pages. With some testing and research, it may be possible to develop a common language and process for accessing weather and climate data across pages to improve user success and satisfaction.



Figure 3. Users often scan for text related to their task rather than reading all content. Image excerpted from Don't Make Me Think: A Common Sense Approach to Web Usability, Second Edition by Stephen Krug. Copyright © 2006. Used with permission of Pearson Education, Inc. and New Riders.

Formal usability testing offers support in resolving these issues. In these tests, a user is given a task to perform on the website in question (Fig. 3). On the Western Regional Climate Center (WRCC) pages, a sample task might be: *Download a text file of daily temperature and precipitation data for Reno, Nevada for the month of August 2013 in metric units.* A facilitator familiar with the site observes the user performing the task and prompts the tester to discuss their actions on the site. It is advisable that the testing is documented with video and screen capture so that all members of the group creating the site can reference the test results throughout the development of the site.

The beauty of this process is that significant gains are typically seen for a relatively small amount of time and resources. For a basic usability study, Nielsen (2000) suggests that testing only 5 subjects can reveal 85% of design issues (Fig. 4).

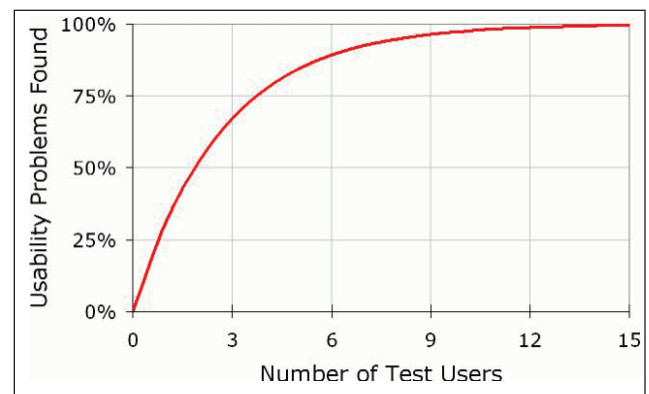


Figure 4. Five test users will typically uncover 85% of usability problems. Note that zero test users uncover zero problems! Image source: Nielsen Norman Group, <http://www.nngroup.com/articles/why-you-only-need-to-test-with-5-users/>

The testing process typically looks like this:

- Group defines target audience and seeks 5 testers who meet this target.
- Group defines 1-2 tasks they think all users in the target audience should be able to or would be likely to perform on the site
- A “lab” is set up where a webcam observes tester, and tester’s actions on the screen are also recorded. This can be done with a variety of software such as Camtasia (see references).
- Tester performs task(s) under supervision of facilitator.
- After testing is complete, group observes videos and facilitator notes and decides how to proceed in making the site more usable.



Figure 5. Users often don't use the site as developers expect! Image source: blog.templatemonster.com

This process is extremely valuable since it highlights one of the fundamentals of usability, letting the user dictate what is usable and intuitive rather than the designer (Fig. 5). It may seem that a large budget and many iterations of testing are needed to improve a web product, though as Krug (2005) points out, "One of the nicest things about usability testing is that the important lessons tend to be obvious to everyone who's watching. The serious problems are hard to miss." In the video examples of tests shown at the Usability Week workshop I attended, it was often very clear what changes were needed to make a site more usable. Things like changing words and phrases or moving the location of an important component to where users said they expected to find it were immediately apparent. Though we have not embarked on testing of our own yet, we hypothesize usability errors will stand out on our sites in the same manner.

To get a feel for web usability principles and benefits, it is an interesting exercise to perform your own self-assessments as you use the web. We all have web pages we visit often and enjoy using, as well as those that have frustrated or annoyed us into never returning. What makes the difference between those pages that delight us and those that turn us away? Is it the ease and intuitiveness of clicking through to our desired content, the visual harmony of the page, or some other factor? As you use the web to perform various tasks, consider why you decide to click where you click. What tells you it is a clickable area? What do you expect will happen when you click there, and does the result of your click meet your expectations? Where do your eyes

move around a web page, what text do you read and why? These exercises can provide great insight to how to approach the design of sites that provide weather, climate, and other environmental data.

At the WRCC, we are striving to implement usability concepts in websites under development and about to embark on formal usability testing on our new interface for the ACIS database. Our improvements and insights from this and future testing will hopefully reduce the data acquisition frustrations of resource managers throughout the West. I look forward to sharing the results of this testing with *Mountain Views* readers in a future issue.

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In late summer, I returned to the Mt Hicks area of the Bodie Mtns, north of the Mono Basin in eastern California. Primarily this was to check plots in the two remote stands of limber pine on the peak, but I was also eager to see the results of the August 2013 Spring Peak Fire, which burned 5800 ha in the eastern Bodie Mtns. Curious about the large patches of unburned sagebrush within the perimeter of the burn, I asked BLM wildlife biologist Sherri Lisius recently what she knew. The answer intrigued me, and I am happy to reprint a story that Sherri had written about fire management in this and other fires in the region.

– Editor

Reprinted from *BLM News Bytes*, 2013, Issue 595

Successful Sage-Grouse Habitat Protection in Spring Peak Fire Management

Sherri Lisius

Bureau of Land Management, Bishop, California

In all wildfire incidents, human safety, including firefighters and the public, is the highest priority. For the Spring Peak Fire another priority was preventing the loss of important cultural features, including the ghost towns of Bodie and Aurora. The Spring Peak area is also important habitat for the Bi-State greater sage-grouse, now proposed for listing as threatened under the Endangered Species Act. The sage-grouse is a chicken-sized bird that relies on sagebrush for food and cover (Fig. 1). It was a third priority that islands of habitat were preserved for the sage-grouse and other sagebrush obligates such as pygmy rabbits.



Figure 1. Male sage-grouse inflate large air sacs of olive-green skin and yellow combs to attract mates. Photo: Bob Wick, BLM

A common method of wildfire management is to create a perimeter with roads, handline, or dozers, and burn all the green within that perimeter. This ensures that no fuels remain to reignite, but also destroys wildlife habitat. In

the Spring Peak Fire and the nearby Indian Fire of 2012 [in the Cowtrack Mtns, along the eastern Mono Basin], the Bishop BLM and the USFS worked with the Incident Commander and the fire team (Fig. 2) to keep firefighters and public safe, protect the ghost towns, and allow for some wildlife habitat to remain in the form of unburned islands, primarily made up of sagebrush and bitterbrush. These green islands provide a natural seed source to help the area revegetate after the fire (Fig 3).



Figure 2. BLM Bishop Field Office Manager Steve Nelson shows BLM California State Director Jim Kenna a map of islands of sagebrush that were preserved within the Spring Peak fire perimeter. (Left to right: BLM California State Director Jim Kenna, BLM Bishop Field Office Geologist Collin Reinhardt, BLM California State Office Energy and Minerals Branch Chief Steve Kupferman, BLM Bishop Field Office Manager Steve Nelson, BLM Bishop Field Office Wildlife Biologist Sherri Lisius, and Fish and Wildlife Service Wildlife Biologist Steve Abele). Photo: Martha Macial, BLM

Based on radio telemetry data collected on sage-grouse after the 2012 Indian Fire, these islands also provide important habitat for sage-grouse (Fig. 4). If the area around the islands comes back with native grasses and forbs, the grouse will use these sagebrush islands during the summer after the burn to rear their broods.

Saving the islands is exciting because 1) it helps the area recover, 2) sage-grouse habitat remains within the fire perimeter, 3) other wildlife like deer, pygmy rabbits, and songbirds can also use these islands, and 4) it provides a way for resource management to be integrated into wildfire management. In the Spring Peak Fire, 1,640 acres of islands were preserved, within the 14,230 acres of the fire.



Figure 3. Two views of unburned islands. Photo: C. Millar



Figure 4. Male sage-grouse defend individual territories within leks, strutting with tails fanned and emitting plopping sounds from the air sacs on their chests to attract females. Photo: Bob Wick, BLM



Figure 5. Where the fire could not be managed for habitat islands, the sagebrush steppe burned extensively. Photo: C. Millar

Book Review

Alpine Treelines: Functional Ecology of the Global High Elevation Tree Limits

Reprinted with permission from *Arctic, Antarctic, and Alpine Research*; Originally published as: *Arctic, Antarctic, and Alpine Research*, Vol. 45, No. 3, 2013, pp. 420–424 DOI: <http://dx.doi.org/10.1657/1938-4246-45.3.420>

Alpine Treelines: Functional Ecology of the Global High Elevation Tree Limits. By Christian Körner. Basel: Springer, 2012. 220 pp. ISBN: 978-3-034-80395-3.

Review by: David M. Cairns, Texas A & M University, College Station, Texas

Christian Körner has been at the forefront of research investigating treelines, and in the late 1990s and early 2000s he proposed a unifying theory to explain the global occurrence of this high-elevation phenomenon (Körner, 1998, 1999, 2005, 2007). Since the early publication of this work, he has collaborated with others to refine the theory and to gather additional data to support his view of why treelines occur. This book is a culmination of that line of thought and lays out his ideas in a clear fashion that is richly illustrated and adequately referenced. The book provides Körner an opportunity to lay out his ideas in detail. For the reader it is a trip through both contemporary and historic literature on treelines that exhaustively evaluates both Körner's thinking about the causes of treeline and a suite of alternative hypotheses for which he finds little support to explain the global treeline phenomenon.

The crux of Körner's hypothesis is that when treelines are considered globally, they closely follow the 6.4°C average growing season temperature isotherm. Körner stressed that when we consider the distribution of upright trees in contrast to seedlings and stunted tree growth forms such as krummholz there is remarkable consistency among treeline position around the globe. The mechanism for the global treeline isotherm approach is that upright full-sized trees are more closely coupled aerodynamically with the atmosphere than are seedlings and short-statured vegetation types common above the treeline. Körner's ultimate conclusion is that the mean growing season temperature plays a central role in determining treeline position and in influencing the mechanisms that translate temperature into a life-form boundary.



Treeline at Palmer Creek drainage, Kenai Peninsula in south-central Alaska. Photo: D. Cairns

One outcome of this conclusion is that the position of treeline should not be viewed or measured in elevation, but rather should be considered in relation to specific thermal conditions on a mountainside (i.e. the global treeline isotherm). When treeline is viewed this way the variability of undisturbed treelines from scales that range from the hillslope to the global are more easily understood. The correlation of treeline with a relatively easily mapped physical phenomenon allows Körner to propose that alpine treeline can serve as a global bioclimatic reference line against which other bioclimatic zones can be compared.

Körner has previously stressed the importance of defining the treeline (Körner, 2007). He commendably proposes a single definition of treeline in this book, and adheres to it throughout the monograph. His definition is based on the tree life form rather than a tree species. In this context, trees are upright woody plants with a dominant stem that reaches a height of at least 3 m. Treeline is then defined as a line that connects groups of trees at their upper-most limit on a mountain slope. Treeline is rarely contiguous and forms a zone on the mountainside that may be interrupted by a variety of environmental conditions and

processes ranging from human activity to substrate availability. Because Körner is interested in climatic treelines, he draws a distinction among sites that are true treelines and those that are merely a tree species limit. If non-native trees are capable of surviving above the local treeline, but do not due to a biogeographic happenstance, Körner does not consider the treeline to be a true climatic one. He therefore discounts its importance from the standpoint of his global theory. Although Körner notes that these cases are uncommon (e.g. the Hawaiian Islands, and *Nothofagus* treelines in New Zealand), some treeline scientists will find this problematic.

After laying the groundwork for his global view of treelines in the early chapters of this book, Körner presents details of the data that support his hypothesis. Alternative hypotheses are considered, and Körner explicitly addresses the influences of reproduction, stress, and nutrient status on the growth and survival of trees at high elevations. He concludes with an overview of the information that he has painstakingly laid out in the first 11 chapters of the book and then places his theory into a temporal perspective by considering what his thoughts mean for treelines in the recent and distant past and what his understanding of treeline may mean for future treelines.

The final chapter addresses the question of whether treeline is in equilibrium with climate, and, if so, at what temporal scale this equilibrium develops. Körner surveys the literature for evidence in the recent and distant past to address this question. He finds that in the recent past (<200 years) treeline does not seem to be in equilibrium with climate changes. The climate has changed too rapidly to allow for adult trees to track with the climate. Körner assumes a lag time of greater than 50 years between climate change and the equilibration of the treeline. This is due to factors including the length of time that it takes for a seedling to grow to “tree-size,” and the frequency of adequate seed production. In contrast to the short-term disequilibrium between climate and treeline position, Körner notes that when viewed over longer periods using a variety of paleoecological proxy data, that treeline position is tracking temperatures consistent with what we observe today. Körner’s treatment of the historical data on treeline change is not exhaustive, but is sufficient to illustrate his main point.

One of the great strengths of the approach that Körner takes in this book is the focus on treelines globally. Even without the emphasis on a global treeline driver, the inclusion of data from so many different treeline sites outside of the northern temperate zone is refreshing. There is comparatively little treeline research published from the tropics and it is nice to see so much of that work referenced in one volume.



Treeline at Palmer Creek drainage, Kenai Peninsula in south-central Alaska. Photo: D. Cairns

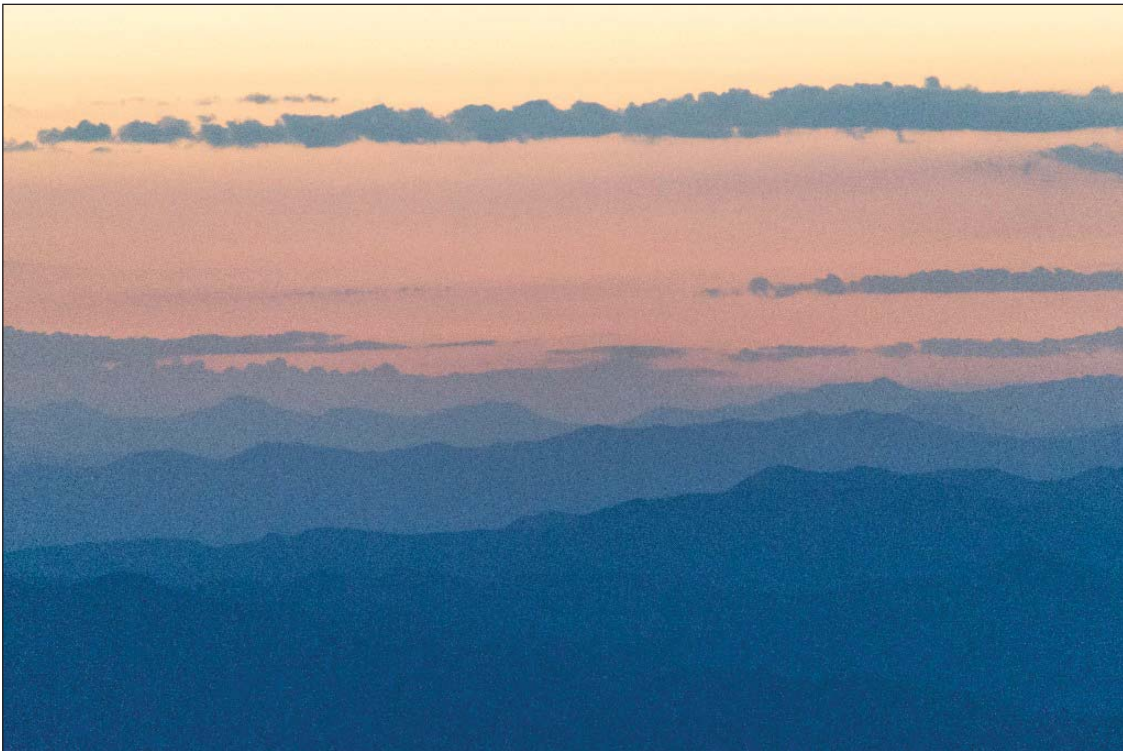
Although Körner provides a wealth of data in support of his hypothesis, he will have critics. Körner’s concentration on treeline as a global phenomenon disregards the impact of local conditions that may influence the pattern and position of treeline. He acknowledges that specific disturbance types such as herbivory, fire, wind, and human activity can have local influences on the tree survival and treeline position, but these are not the emphasis of his monograph. For those readers interested in detailed discussions of processes that lead to fine-scale heterogeneity at treelines, other sources will offer a much greater depth of discussion. The coarser scale explanations of a phenomenon, however, are worth considering. Readers familiar with hierarchy theory (Allen and Starr, 1982) will easily find a way to situate fine-scale questions within the coarse-scale controls laid out here by Körner.

There are several other books that have been published previously on treeline. Körner acknowledges this, and it is useful to know how his work fits into the collection of pre-existing treeline monographs. Earlier volumes have been either aimed at a different kind of audience (Arno and Hammerly, 1984), are location-specific (Butler et al., 2009), or focus on scales below the global (Holtmeier, 2003). This volume is most closely related to Tranquillini’s (1979) *Alpine Timberline*, and in many ways reads as an update on the status of physiological ecological research at treeline, but with an emphasis on the global treeline.

Overall this is an excellent addition to the library of anyone interested in the functional ecology of trees at high elevations. Graduate students and those new to studying treeline should be encouraged to read the text, and those of us who have been interested in treeline research for a long time will undoubtedly find something new in this book.

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View toward the Sheldon Antelope Refuge, from the Pine Forest Range, NW Nevada. Photo: S. Strachan

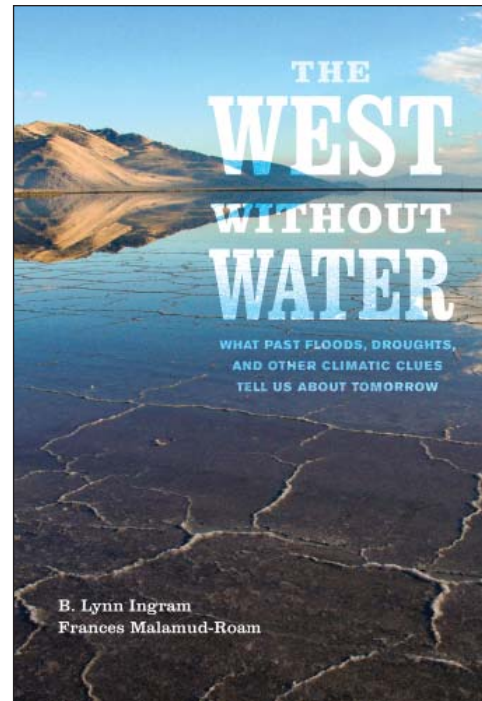
New Book

The West Without Water: What Past Floods, Droughts, and other Climate Clues Tell Us about Tomorrow

University of California Press, 2013, 289 pages
By B. Lynn Ingram and Frances Malamud-Roam

The West without Water documents the tumultuous climate of the American West over twenty millennia, with tales of past droughts and deluges and predictions about the impacts of future climate change on water resources. Looking at the region's current water crisis from the perspective of its climate history, the authors ask the central question of what is "normal" climate for the West, and whether the relatively benign climate of the past century will continue into the future.

The West without Water merges climate and paleoclimate research from a wide variety of sources as it introduces readers to key discoveries in cracking the secrets of the region's climatic past. It demonstrates that extended droughts and catastrophic floods have plagued the West with regularity over the past two millennia and recounts the most disastrous flood in the history of California and the West, which occurred in 1861–62. The authors show that, while the West may have temporarily buffered itself from such harsh climatic swings by creating artificial environments and human landscapes, our modern civilization may be ill-prepared for the future climate changes that are predicted to beset the region. They warn that it is time to face the realities of the past and prepare for a future in which fresh water may be less reliable.



Upcoming CIRMOUNT Conference:

MtnClim 2014

September 15-18, 2014, Midway, Utah

MtnClim 2014, the biennial climate conference sponsored by CIRMOUNT, will convene Sept 15-18, 2014, at the Homestead Resort in Midway, UT, in the high Wasatch Mtns. *MtnClim* celebrates its 10th anniversary with this meeting, the first conference having taken place at North Lake Tahoe, CA in 2004. The program for 2014 includes invited sessions on mountain climate refugia, micro-climate processes, and opportunities for climate adaptation; a session in honor of Dennis Machida on coupled human-social systems in mountains; and a session on early-career scientists' research. Invited talks will feature a 10-year retrospective and prospective of research accomplishments and future needs in mountain-climate science; a national perspective on the role of mountain climate science in emerging policy and applications; a round-up of the climate and weather highlights since *MtnClim 2012*; and an overview of Great Basin

forest ecosystems and their interaction with climate change and bark beetles. As always, contributed talks and posters will be important parts of the agenda. We plan a pre-conference field trip to the Uinta Mountains, and a post-conference resource managers' workshop, both to focus on forest health and climate in the Great Basin and western Rocky Mountains.

Deadline for registration, abstracts, and lodging is July 15 2014; early registration is encouraged as attendance is limited to 120 participants.

MtnClim 2014 Conference Website:

www.fs.fed.us/psw/mtnclim/

For questions, contact Connie Millar, cmillar@fs.fed.us



Mt Timpanogos. Photo: B. Temper

Conference on Mountain Meteorology American Meteorological Society Summer 2014: Dates and Location Pending

Program topics will include:

- Stable and convective orographic precipitation
- Boundary layers and turbulence in complex terrain
- Slope flows and cold pools
- Mountain air quality and chemistry
- The effect of the planetary boundary layer on aerosol and chemical measurements at high-elevation sites
- Mountain waves, rotors, and terrain induced windstorms
- Mountain climate and climate change
- NWP and data assimilation in complex terrain
- Influence of terrain on meso- and synoptic scale predictability
- Wind resource assessment in complex terrain
- Lake breezes, land/sea breezes, and other complex-topography effects
- Hydrological processes in complex terrain
- Results from recent field campaigns: HyMeX, Materhorn, DeepWave, etc.

Watch this website for further information: <http://www.ametsoc.org/meet/meetinfo.html>

and/or contact Daniel Kirshbaum, NOAA, daniel.kirshbaum@mcgill.ca, or Heather Reeves, NOAA, heather.reeves@noaa.gov



Three Fingered Jack, Oregon Cascades. Photo: J Blanchard

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

Oddities of Mountain Weather and Climate

This section of Mountain Views Newsletter highlights unusual mountain-weather events or climate-related phenomena of western mountains. I welcome your comments on processes and observations described, and encourage submissions for future issues. In the story below, I was fortunate to have Nina Oakley tutor me on details of gravity waves and lenticular clouds.

– Editor

Lenticular Clouds Revisited

Connie Millar¹ and Nina Oakley²

¹USDA Forest Service, Pacific Southwest Research Station, Albany, California

²Western Regional Climate Center, Desert Research Institute, Reno, Nevada

Lenticular clouds (Figs. 1, 2), also called lens clouds or mountain wave clouds develop commonly in mountain regions, so why do they qualify as a subject for this section of *Mountain Views Newsletter*? Despite their familiarity, lenticular clouds, like autumn foliage, double rainbows, brilliant sunsets, and full moons, keep turning heads and find us reaching for cameras. More importantly, although most of us can explain the general cause of these clouds – “they form like a standing wave in a river” – I (Connie) realized my knowledge was shallow on questions such as: Under what meteorological conditions, seasons, and times of day do lenticular clouds form? Do they develop in some mountain regions more than others and, if so, why? Are mountain cap clouds (Fig. 3) and lenticular clouds the same thing? Why do lens-shaped clouds exist both over the apex of the mountains and at periodic distances downwind over basins or valleys? Trying to answer these questions to satisfy my curiosity, we offer the following simplistic explanations for a complex meteorological phenomenon.



Figure 1. Lenticular clouds over the Sweetwater Mtns, California, from Molybdenite Canyon. Photo: C. Millar.



Figure 2. Lenticular clouds, Aiguille du Midi, Chamonix, France. Photo: J. Blanchard

When fast moving (≥ 25 knots), stably stratified air is forced to rise over a topographic barrier, gravity waves, or “mountain waves” can develop in the atmosphere (Fig. 4). The mountain barrier deflects air up along its windward side, and, as the air crests the summit, gravity acts as a restoring force to bring the air back towards equilibrium. When the air is pulled back towards equilibrium on the lee side of the mountain barrier, the air will “overshoot” equilibrium level and oscillate, much like a floating cork pushed underwater will bob several times before returning to a stable position. This oscillation is referred to as a mountain wave. These waves are best formed where a stable atmosphere exists above the topographic barrier (in western North America about > 700 mb or 10,000 ft, Vieira 2005). When sufficient moisture is present and air is cooled to the point of condensation, lenticular clouds, known formally as *altocumulus standing lenticularis* clouds, can develop at the mountain wave crests. On the lee side of the wave crest, as the air descends and warms, the



Figure 3. Cap cloud on Middle Sister, Central Oregon Cascades. Photo: J. Blanchard

cloud evaporates, helping to shape the lower boundary of the lenticular cloud. The oscillation of mountain waves can result in lenticular clouds appearing for many miles downstream of the mountain barrier until their energy is dissipated via friction with the surrounding air (Fig. 5).

These clouds appear stationary, though very dynamic air is continuously flowing through the mountain wave like a conveyor belt, with condensation on the upslope side of the wave and evaporation on the downslope side. Lenticular clouds can occur at various heights in the atmosphere depending on the vertical wind and temperature profiles, which control whether the mountain wave is propagating vertically or horizontally. Lenticular clouds developed at higher elevations may appear thicker and larger due to cooler temperatures allowing for greater amounts of condensation.

Mountain waves can be created by terrain of varying height, but the best type of wave generator is elongated high terrain perpendicular to the flow. Short cone-shaped peaks are not good generators of mountain wave clouds, although lenticular clouds can develop over such summits if they are of sufficient height, such as Mt. Shasta or Mt. Rainier. Thus, the type of topography in a mountain region influences the nature and abundance of lenticular clouds.

In addition to lenticular clouds, other types of clouds can be created in a mountain wave situation. With sufficient moisture, a lenticular cloud with a cloud base below the mountain peak called a cap cloud will form over the barrier (Whiteman 2000). A turbulent eddy called a rotor forms on the lee side of the terrain barrier when mountain waves are present. Rotors rotate about an axis parallel to the mountain range and are often observed below

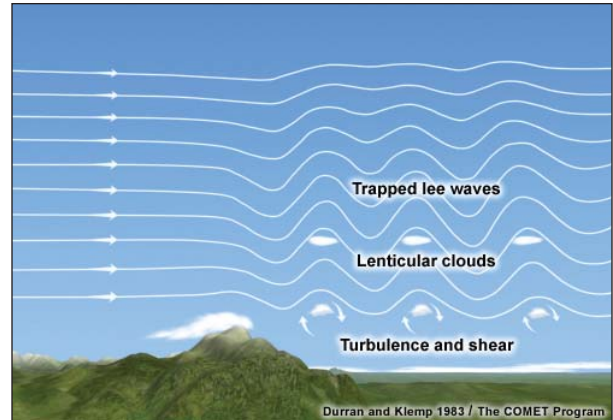


Figure 4. Schematic showing formation of mountain waves and related features. As stable air flow is deflected upward and over a perpendicularly oriented topographic barrier (mountain range), cap clouds can form over the summits. Lenticular clouds can form in the peaks of the oscillating air flow (mountain wave) downwind if adequate moisture is present. Trapped lee waves, whose energy does not propagate vertically because of strong shear or low stability, occur in the higher atmosphere. Rotor clouds can occur downwind of the topographic barrier near the surface as a result of turbulence and shear. From: UCAR COMET© Program educational materials, <https://www.meted.ucar.edu/mesoprim/mtnwave/frameset.htm>

lenticular clouds. The intensity and organization of rotors is tied to the strength of the mountain waves and wind velocity. When sufficient moisture is present, a rotor cloud will form at the top of the rotor circulation (Whiteman 2000, Xue 2007).

The structure of mountain wave winds and formation of lenticular clouds and related processes are determined by the size and shape of the mountain and by the vertical profiles of temperature, wind speed and moisture in the impinging flow. These conditions thus develop within a variety of synoptic regimes, and depend on details of regional climate and topography. In many parts of western North America, lenticular clouds can occur in any



Figure 5. Lenticular clouds, Mt Denali, Alaska. Photo: J. Littell.

season, though are most prevalent in fall, winter or spring when the jet stream is likely to pass over the region (Lester 2004).

Because the nature of mountain waves can be highly turbulent, with abundant shear winds aloft and often accompanied by strong, gusty rotor winds at the surface, the presence of lenticular, cap, or rotor clouds indicates hazardous conditions for pilots. Strong mountain waves can develop regardless of water content in the air. Under dry atmospheric conditions, mountain waves occur without lenticular, cap, or rotor cloud formation. These conditions are especially serious for airplanes because the existence of these waves is not visually apparent.

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Figure 6. Lenticular clouds, Owens Valley and the Sierra Nevada. Photo: J. Blanchard

The Ever-Changing Celebration

Margaret Eissler, Ranger Naturalist

National Park Service, Yosemite National Park, California

Reprinted from *Yosemite Guide*, 2013, Vol 8, page 18

The year has always seemed to me a circle—a ring with a jewel at the top. The jewel is summer in Tuolumne Meadows, a gleaming, magical celebration of time and place.

Tuolumne Meadows stands at 8,600 feet above sea level. The designated Wild and Scenic Tuolumne River meanders through broad subalpine meadows surrounded by peaks and domes. In the high mountains, winter lasts most of the year. The jewel, then, is not simply “summer” but rather three seasons—spring, summer, and fall—compressed into the calendar months typically called “summer.”

Everything has to happen quickly in this short time. It’s a wild dance, a flurry of activity. The early blooming of shooting stars and buttercups begins a rapid succession of flowering events across eight to ten weeks, an intense period of buds unfolding to bloom, then seed, then plants stocking up energy in their roots in preparation for next spring. Mosquitoes and dragonflies emerge from the lakes and ponds. Frog eggs hatch into tadpoles. Lodgepole pines release their pollen. Deer give birth to fawns. Baby Belding’s ground squirrels and yellow-bellied marmots

appear. Birds mate, nest, lay eggs, and feed nestlings that quickly fledge. There is no time to lose. It’s all about reproductive survival. It is simultaneously serious business and a vibrant celebration of life.

If you took the same walk everyday, you would notice something different each time: a new flower in bloom, another gone to seed; a robin’s nest brimming with demanding, hungry mouths, then an empty nest; a hawk, dive-bombed by jays and robins, sitting on a branch, eating one of these fledglings; the hermit thrush singing its flute-like song and then, suddenly, mid-season, silent.

Summer soon overlaps the end of spring. The higher sections of the meadows dry and turn golden brown. The river, once loud and raging, dwindles, becomes quiet and easy to cross. The white gentians (*Gentiana newberryi*) show up with frilly petals. Pale green dots inside lure pollinators to nectar deep within their bell-shaped flowers. This and two other gentian species are the last to bloom in these high meadows. They signal the coming of fall and the approach of winter.

Although every year is different, I’ve noticed autumn arriving around the third weekend of August. You can hear the seasonal change. Wind blows through the tops of the lodgepole pines. The



Aspen leaves. Photo: J. Wyneken

kingfishers arrive and make their rattling calls as they fly the river course. The Townsend's solitaire, a robin-like bird, sings endless warbling songs from the tops of trees, seemingly without taking a breath. The chickaree, also known as the Douglas tree squirrel, becomes more active and noisy as it makes last preparations for winter. The bilberry, a meadow ground cover, turns fiery orange and red. The days are noticeably shorter. Freezing nights frost the meadow grasses and sedges. There's an excitement in the air, a sense of urgency and anticipation. The bears are extra hungry. It could snow any time.

A raven clicks and croaks in the tree just beyond my cabin door. Brewer's blackbirds flock together, "whirl in the autumn winds" as the poet says, and leave their many tracks in the snow. It's the end of September, time to pack up and move to lower elevations before the big snowstorms come. Some animals stay, but most leave for the long winter.

All of us join this wild celebration when we visit the high mountains. Clearly we are just one small part of everything that is going on. We become aware that plants and animals have no time to recover if something goes wrong—like the damage caused by a few people walking on these fragile meadows. This awareness inspires respect, a thoughtfulness about how to be in this place: where we put our feet, where we picnic, how fast we drive. Everything is alive, vibrant, yet delicately balanced within this short span of time.

The year has always seemed to me a circle—a ring with a jewel at the top. I wear it always and try to live up to what it stands for: a marriage of sorts, a commitment to place, an awareness of relationship with everything else. Maybe we all wear place rings. We all live within the circle of the year and a cycle of seasons. Which ring do you wear? Where is your place?



Valerie P. Cohen, "June Snow on Tenaya Lake, Yosemite," Watercolor, 22" x 30"

Contributing Artists

I hope you enjoy the mountain clouds photography highlighted in this issue of *Mountain Views Newsletter*. Please feel free to send me your favorite mountain tree photos, a topic for photographs in the Spring 2014 issue. Many thanks to the following cloud photographers:

Thomas Angeli, Journalist, Mühlethurnen, Switzerland;

Jehren Boehm, mountaineer, bike mechanic, and oft research assistant, Department of Geography, University of Nevada, Reno, NV;

Jim Blanchard, retired Professor of Outdoor Education, University of Oregon, Eugene, OR;

Greg Greenwood, Executive Director, Mountain Research Initiative, Bern, Switzerland;

Jeff Hicke, Associate Professor, Department of Geography University of Idaho, Moscow, ID;

Jeremy Littell, Research Ecologist, USGS, Alaska Climate Science Center, Anchorage, AK;

Kelly Redmond, Deputy Director and Regional Climatologist, Western Regional Research Center, Desert Research Institute, Reno, NV;

Scotty Strachan, Environmental Research Coordinator, Department of Geography, University of Nevada, Reno, NV;

Stu Weiss, Chief Scientist, Creekside Center for Earth Observation, Menlo Park, CA.

Reproductions of watercolor paintings of mountain landscapes are by Valerie Cohen. Valerie often accompanies our GLORIA expeditions in the White Mountains, CA, where we are fortunate to view her original works, and peek over her shoulder as she creates new pieces. Valerie lives in the Tahoe region of the Sierra Nevada, CA. More of Valerie's work can be found at her website: <http://valeriepcohen.com/>

Poetry featured in this issue is from Norman Schaefer, Port Townsend, WA, whose mountain verse I have featured before. The short poems in this issue are from his new book, *Fool's Gold*, 2013, La Alameda Press, Albuquerque, NM: www.laalamedapress.com/



The Sisters, Sweetwater Mtns., NV. Photo: J. Boehm

Mountain Visions

Thin ice:
some of Mono Creek
will be staying here tonight.

I came to Little Five Lakes
to be alone for a while,
so this monsoon blew in
at just the right time.

Clouds cover the stars over Mt. Clarence King
and darkness comes incomprehensible.
I can't explain anything tonight.

– Norman Schaefer



Valerie P. Cohen, "Storm Over Carson Valley," Watercolor, 22" x 30"



Valerie P. Cohen, "Mount Morrison," Watercolor and Ink, 22" x 30"

I have wandered
far and wide
in the Sierra Nevada,
but nothing like
the autumn wind tonight.

One big storm
and the creek thinks
it's a river.

– Norman Schaefer



South Sister from Broken Top, Oregon Cascades. Photo: J. Blanchard