

MOUNTAIN VIEWS

The Newsletter of the Consortium for Integrated

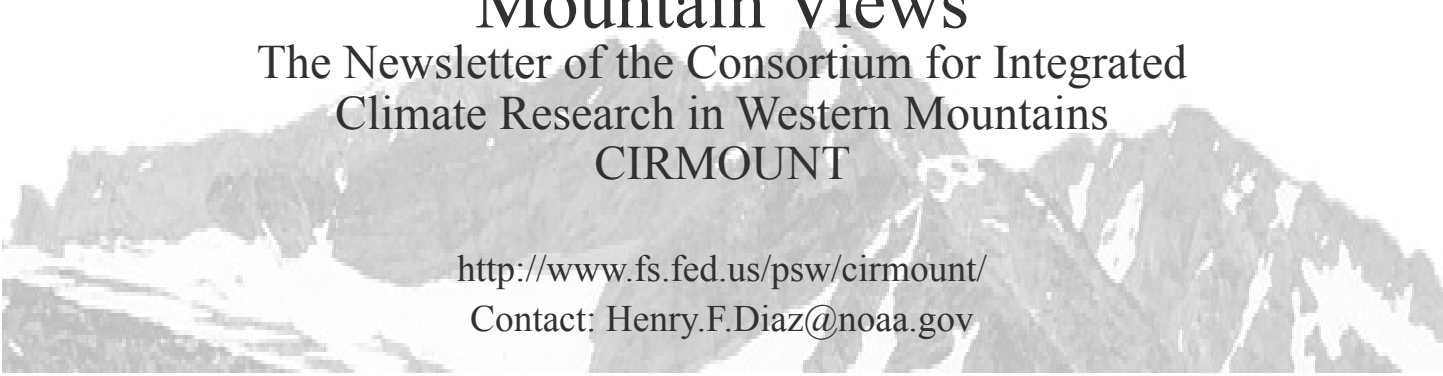
Climate Research in Western Mountains

CIRMOUNT



Informing the Mountain Research Community

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Mountain Views

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

<http://www.fs.fed.us/psw/cirmount/>

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The Mountain Views Newsletter

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Welcome to Mountain Views, the biannual newsletter of the Consortium for Integrated Climate Research in Western Mountains (CIRMOUNT). With our fifth issue of the Mountain Views Newsletter (MVN), we begin our third year of publication reporting news of mountain climate research and resource management. CIRMOUNT provides a forum for the mountain science community in western North America to integrate and communicate research from diverse disciplines related to climate. CIRMOUNT also seeks to promote awareness and solutions to societal issues arising from anthropogenic interference in the mountain climate system.

We began summer by convening MTNCLIM 2010, the fifth mountain climate conference that CIRMOUNT has sponsored since 2004. MTNCLIM conferences are the flagship effort of CIRMOUNT and dedicated to communicating mountain-climate sciences and effects of climate variability on ecosystems, natural resources, and conservation with focus on western North American mountains. MTNCLIM conferences feature invited and contributed talks, poster sessions, and working-group sessions. A post-conference workshop for natural-resource managers is held to address implications of climate variability and climate change in conservation and management. MTNCLIM now convenes every two years. MTNCLIM 2010 was held June 7-10, 2010 in Blue River, Oregon and was hosted by scientists and managers at the H.J. Andrews Experimental Forest. In this issue of MVN, Melanie Lenart (University of Arizona) summarizes key themes and reports highlights from talks, posters, and discussions of MTNCLIM 2010.

This summer also saw completion of the third 5-year re-measurements of GLORIA (Global Observation Research Initiative in Alpine Environments) target regions in the West. GLORIA is an international project based in Vienna Austria that has a goal of monitoring responses of alpine plants to climate change around the planet. Target regions in localized bioclimatic mountain regions are established with replicate plots on four adjacent mountain summits, and a consistent monitoring protocol is used at each target region. Whereas target regions had been established

in Europe, Asia, and South America by the early 21st century, North America was lagging. In 2004 CIRMOUNT established the North American GLORIA chapter (co-lead by Dan Fagre, USGS and Connie Millar, USFS), and installed the first three target regions (Glacier National Park, and one each in the Sierra Nevada and White Mountains). As of 2010, 15 target regions are now established in western North America, the latest being Mt. Langley in the Sierra Nevada, California. Three more are in active planning, and interest has been expressed for at least two additional target regions.

With the GLORIA target regions now in re-measurement phase, interpreting changes against baseline data begins. For several of the target regions, the 5-year re-measurement indicated greater numbers of rare plants than baseline. One of many challenges is to determine whether this is a real effect or an artifact of measurement. Whereas GLORIA scientists attempt to keep time of year the same for the 5-year monitoring, annual weather can induce flowering at different times and abundances, and our ability to detect rare alpine plants may reflect this variability.

This effect of timing on plant and animal life-cycle events is influenced not only by short-term weather, but also by long-term climate trends. Phenology, the study of these cycles, is an important element of climate research. The USA National Phenology Network (NPN), a program that coordinates and supports research and monitoring of life-cycle events and timing, was summarized in a 2008 MVN report. In the current issue, Mark Losleben (NPN, University of Arizona) describes a new effort of NPN, the Biophysical Program, which has the goal to understand relationships of life-cycle timing to annual weather and longer-term climate change.

Whereas CIRMOUNT's primary focus is to promote and integrate climate-related research in western North America, the consortium must keep in mind the role of our region in the world's mountain geo-ecosphere. One of the Work Group efforts of CIRMOUNT focuses on International Relations, and the international Mountain Research Initiative is closely tied to CIRMOUNT. In this issue of MVN, John All (Western Kentucky University)

contributes an article on climate change in the central Himalayas of Nepal, where impacts of change are dramatic and significantly affecting the livelihood of local communities.

Looking forward to fall 2010, CIRMOUNT is sponsoring its eighth session at the annual meeting of the American Geophysical Union (AGU) in San Francisco, California, on Friday, December 17. The CIRMOUNT session is in the Global Changes section of AGU (GC-28), and is titled, "Ecosystem Responses to Fine-Scale Climate Variability in Mountainous Terrain". Four invited presenters include David Charlet (College of Southern Nevada), Frank Davis (University of California Santa Barbara), Michael Goulden (University of California Irvine), and Lara Kueppers (University of California Merced). Thanks to all who submitted abstracts—the session looks packed full of exciting new research, and we look forward to seeing many of you in December. As has become custom, we will organize an informal dinner at a local restaurant during the AGU week for CIRMOUNT scientists and friends. Watch for email and/or contact Connie (cmillar@fs.fed.us) if you're interested to attend.

Other changes coming for CIRMOUNT include additions to the group of consortium coordinators. Joining us are Andy Bunn (Western Washington University), Jeff Hicke (University of

Idaho), Gregg Garfin (University of Arizona), Jeremy Littell (University of Washington), and Christina Tague (University of California Santa Barbara). We look forward to new ideas they will infuse into CIRMOUNT activities and direction. Stepping from active into advisory roles from our coordinating group are Dan Cayan (USGS), Lisa Graumlich (University of Washington), Malcolm Hughes (University of Arizona), Connie Woodhouse (University of Arizona), and Tom Swetnam (University of Arizona). Many thanks to these founding 'parents' of CIRMOUNT for their active leadership over the past years; we anticipate their involvement will continue in important ways. Finally, one of us (Henry Diaz) is also stepping down from an active role in CIRMOUNT. Henry is relinquishing his role as primary editor of MVN, a newsletter he established and has maintained through the three years of its existence. Connie will continue as MVN editor, and she will invite participation from one or more co-editors. Should any of you be interested, contact Connie.

Our best wishes for a productive autumn conducting and applying mountain climate research.

Introducing the USA National Phenology Network Biophysical Program

Mark Losleben

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Overview

Mountain Views readers read about the USA National Phenology Network (USA-NPN) in the Spring 2008 issue. Since then, the USA-NPN has continued to grow and add services including detailed plant phenology observation protocols for over 200 plant species and an advanced user interface for data entry. However, this article will focus on the newest USA-NPN addition: the Biophysical Program.

On January 1, 2009, the USA-NPN (www.usanpn.org) launched the Biophysical Program. The overarching goal of the Biophysical Program (BP) is to connect phenology with climate through the integration of phenology observations and meteorological measurements at sites across a broad a spectrum of environments. Using coordinated, standardized protocols enables evaluation of relationships between weather, climate and phenology, and can facilitate development of climate change adaptation strategies. Elevational-latitude gradient networks enable climatic matching to test hypotheses while controlling for climate, thus permitting evaluation of variables such as atmospheric circulation (synoptic flow), day length (solar isolation), components of ecosystem interactions and synergisms, atmospheric pressure regimes, and a host of biotic and abiotic factors.

A comprehensive, inexpensive method to track biological conditions nationally and globally is crucial to evaluate ongoing and future climate change effects. Current knowledge of climatic influences on plant and wildlife species phenology is incomplete. Spatially extensive, co-located phenology and climate measurements are also required to make the connection to remotely sensed products. Elevation gradients offer logistically feasible spatial coverage, and networks of elevation gradient sites across broad latitudinal extents opens opportunities for climatically matched comparative research, given that all site measurements are standardized and coordinated. Thus, the products of this set of co-located phenological and meteorological observations, hereafter referred to as PhenoMetNet, will inform modeling efforts that are key to developing realistic adaptive and mitigation strategies for our future in a rapidly changing climate.

Key operational elements of this approach include co-locating phenology observations with weather and remote sensing mea-



Lilac phenology provides an historical biological indicator of climate change. Cloned lilacs are important as climatic calibration species due to their fixed genetic information. Lilacs became popular with early mountain settlers for their hardiness, reputed to survive temperatures of -40°C . Photo credit: Mark Losleben, Model: Connie Woodhouse.

surements. In addition, sites along elevational gradients, over as great a latitudinal range as possible, offer maximum potential return on the financial and labor investments.

Thus, the overarching goal of the Biophysical Program will be met through the development of elevational-latitude gradient networks, PhenoMetNets, capable of tracking current conditions, which will also serve as field test and evaluation sites of adaptation strategies to future climate change.

The author became the Coordinator of this new NPN program in January 2009, after serving as the Assistant Director of the USA National Phenology Network during its inaugural first two years. Prior to this Mark served as the Manager of the Mountain Climate Program at the University of Colorado, Mountain Research Station, for 26 years.

The Biophysical Program and the Phenometnet

Integration of spatially extensive phenology data with near and long term climate forecasts is a powerful agent for human

adaptation to future climate change. With this new program, the USA-NPN continues advancing towards this goal of adaptation through facilitation, resource sharing, and collaboration. The facilitation includes the development and dissemination of a template for implementation and operation of co-located, integrated environmental monitoring sites that when aggregated result in elevational and latitudinal gradient monitoring and evaluation networks, or PhenoMetNet's. The intent of the BP is to integrate the simultaneously acquired PhenoMetNet's phenology, climate, and remote sensing data to stimulate creation of research products that enable spatially complete and continuous national phenology coverage. The BP thus expands the USA-NPN scope to include the development and incorporation of phenology in biophysical monitoring programs across the nation by helping to create the framework, encourage the monitoring, and providing phenology data services, but seeks the help and advice of the community to best design integrated weather/climate and remote sensing data management systems.

The USA-NPN Biophysical Program plans to sprout elevational-latitudinal gradient networks through creation of a site development template and by publicizing the concept of co-location and integration. The planned PhenoMetNet template, which will be documented in a manual available through the NPN-USA BP, will be a detailed resource, including instrumentation, instal-

lation, and observational protocols, intended as a service to all interested in participating in this effort. The purpose of the template is to provide a basis for standardized meteorological and remote sensing data by detailing installation, operation, and maintenance protocols to guide all interested in partnering in an elevation-latitudinal gradient network effort.

This PhenoMetNet template is as much a communal work as the community at large wishes it to be. All forms of input and resources are most welcomed that promote the development of a cohesive network of field sites serving the climate and environmental research communities. Meanwhile, it is being developed and tested this summer 2009, at the Rocky Mountain Biological Laboratory (RMBL), Gothic, CO. Support for this first BP endeavor comes from an agreement between USA-NPN and RMBL to collaborate on development of the program, pilot project, and template. Support for implementation of the prototype at RMBL is derived from a recent NSF grant to RMBL to facilitate installation of a "Distributed Environmental Sensor Network," referred to as RMBLnet. This co-located phenology-meteorology-remote sensing elevational gradient network (Fig. 1 and Fig. 2) will utilize USA-NPN phenology protocols, include cloned lilac plants, and feature a full suite of meteorological instrumentation. Expanded solar instrumentation and a RGB camera at each site are for surface remote sensing, which facilitates scaling from surface

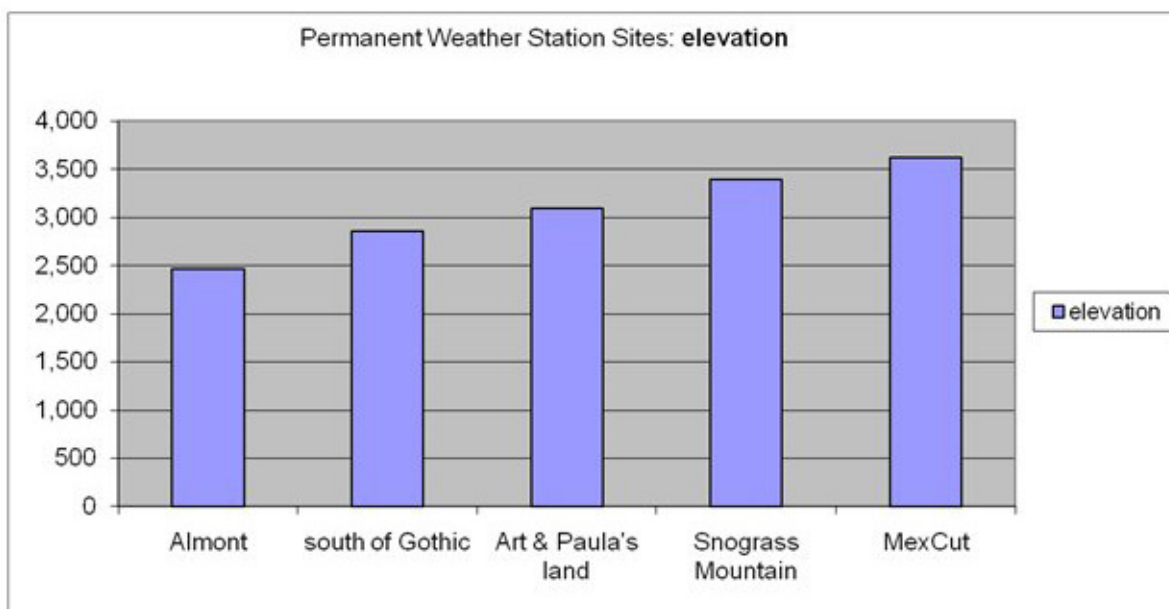


Figure 1. Station place names and elevations, in meters, of the five permanent stations comprising the RMBLnet integrated gradient network. Numerous portable stations will also be part of this network. Graph provided by Dan Jones, RMBL.



RMBLnet home. The view is overlooking Gothic, CO, and part of the area covered by the RMBLnet. Crested Butte is to the left. Photo credit: Dan Jones, RMBL.

to space-based remote sensing phenology products, and supports efforts to attain full global and temporal coverage in the future.

Site Components

Phenology

As envisioned by the program and implemented in the prototype, USA-NPN will serve as the central clearing house and repository for all phenology aspects: national and regional lists of plant species, standardized observational protocols, an advanced user interface for data entry, and coming soon, data visualization, download, and archival services. Just go to www.usanpn.org, select the plant species, and enter the observations on that page. In addition to native species, cloned lilac plants (adding to a 50-year-old program <http://www.usanpn.org/?q=content/lilachoneysuckle-program>) are important as calibration species due to their fixed genetic information. USA-NPN is in the process of developing animal phenology monitoring programs for implementation in 2010; hence, animal monitoring could be included as well.

Climate

Accumulated weather data is necessary to determine the climatic phenology controls, and standardized sensors and data collection protocols are critical to this end. These standards are also necessary for effective inter-site research, and this aspect is addressed by the USA-NPN BP template. An example of an exhaustive equipment list for both permanent and portable weather station installations is available from the RMBLnet project upon request. In the near-term, climate data will be archived at RMBL. A BP long-term data archive and access program, which will make data

from this project and others widely available, is anticipated.

Remote Sensing

Remote sensing offers truly complete spatial coverage, but usually provides mixed species information. Therein, the phenology challenge is to relate land surface phenology (LSP) to species level conditions. Co-located observations and measurements will advance the efforts to make this connection. Unlike satellite based remote sensing of phenology, surface remote sensing of phenology research has received much less attention and resources. However, effective scaling efforts require this level of data collection for scaling to satellite products; thus to make the link to full global and temporal phenology coverage. [A reference for a surface remote sensing algorithm and instrumentation is provided by J.P. Jenkins et al., *Agricultural and Forest Meteorology* 143 (2007) 64–79].

Next Steps—Expanding the Scope Beyond the Prototype

The PhenoMetNet template being developed through the RMBLnet project will be a guide and instruction manual for establishing new phenology/climate observation installations. The template will describe the design, implementation, operation, and maintenance of sites to gather co-located phenology, climate, and remote sensing data. This template will provide a set of observing and instrumentation standards but will also be an evolving product, reflecting changing end-user needs and developing technologies.

Established monitoring sites may already have all but the phenology components of this co-location concept. In this case, the USA-NPN has done most of the work to take the next step by providing plant lists, detailed observation protocols, data entry, and archive services. So, to add phenology, is to go to www.usanpn.org, select the plant species, and enter the observations.

At less developed sites, perhaps the addition of some instrumentation is required. For example, a camera or webcam, or solar instrumentation would add the surface remote sensing capability. Guidance on instrumentation and protocols will be available through the PhenoMetNet guide.

Adoption of this co-located, integrated monitoring approach by a few groups and organizations could rapidly advance the realization of an elevational-latitude gradient network. Some well-placed examples are CIRMOUNT in western North America, CORFOR in the American cordillera, and attendees of the Perth, UK 2010 meeting representing world-wide elevational transect

opportunities across broad ranges of latitudes.

Conclusion

The opportunity to capitalize on current technological developments that enable coordinated efforts to simultaneously monitor, assimilate, and evaluate a full spectrum of environmental factors, and the need to do so, is upon us. With these tools, we can meet this challenge to design adaptation strategies for a climatic future without precedent.

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Climate Change in the Central Himalayas of Nepal

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Mountain weather is often unpredictable, and the ongoing and future climate changes are likely to make things even more uncertain. These and other factors have made research in the Himalayas troublesome. In the past, field research could be timed with the monsoon—if you wanted generally clear weather, you would plan to go in October before conditions became too cold to work in. If you wanted to study wildflowers, you would go in July. Why July? The yaks move up the valleys in April, eating as they go. By June, they are in the higher pastures and the monsoon has begun and new growth springs up, especially in the lower elevations. In July the wildflowers are perfect. By September the yaks have begun moving down the valleys because of the increasing cold, and yaks trains full of trekking supplies have begun to move up the valleys as the rains end. As a result, by early October the meadows are mowed flat, down to the dirt. A yak is a huge beast and when carrying heavy loads up steep slopes, it consumes many tons of biomass per year. Alpine meadows do not produce high amounts of biomass, so you end up with a paradoxical situation of both hungry yaks and totally depleted meadows.

With growing local populations of people and increased trekking, this ‘tragedy of the commons’ grows worse every year. Topsoil is slumping off the steep hill slopes in larger and larger sheets. Local water supplies have longer and longer periods of eutrophication created by yak dung (and human wastes) entering water bodies. But in a country with chronic underemployment and a GDP of less than \$1000 a year, any possible income means the difference between mere survival and actual prosperity.

Climate change has begun to rapidly impact the colder regions of the world. The reality of what is happening in many less developed mountainous countries is shocking—vast chasms in the countryside comprised of loose rock - with such massive scars pointing out places where millions of tons of ice recently existed. When you ask the local villagers, they tell you that a decade or so ago, the glacier just disappeared and left a 500 foot deep, half mile wide trench that extends for miles up the mountain valley. A few of these features are beginning to experience bio-colonization. Mosses and lichens are moving in and there are small patches of grass in the oldest and most stable sections of the ex-glacier. These areas will provide fascinating biogeographical



View of the remnants of Ngozumpa Glacier from Gokyo Ri, Sagarmatha National Park, Nepal. Gokyo Lake, to the left, is a RAMSAR site but it is unknown how long the lake will last once the glacier is completely gone.

laboratories for studies in dispersal and colonization over the next few decades as they slowly stabilize.

Plants of all types are thriving in the new environment. When I read accounts of mountaineering exploits from the 1930's and their discussions of the constant snow, or of chopping a tent platform in the ice at Mt. Everest basecamp in October, and I visit the basecamp in the same month and find only rock and pools of water with an air temperature of 65 degrees Fahrenheit, I understand why the plants are doing so well and moving into so many new areas. Grasses into lichen areas, shrubs into grasslands, and lichens into areas not still covered with ice.

The problem for climate change research is that as fast as plants are moving and as beneficial as growing conditions are becoming, sheep, goats, and yaks are already there waiting for them and they are voracious. And humans are cutting wood and extracting various medicinal plants as fast as they can be found.

I am working in Nepal for a year on a Fulbright Senior Fellowship. As part of this fellowship, I am researching climate change in the Himalayas and working with graduate students at Tribhuvan University (TU). Because human extraction of biomass is pervasive—I have personally seen yaks grazing and people



The author taking ground data near Cho La pass, Sagarmatha National Park, Nepal.

digging out juniper roots for firewood at elevations—higher than the summit of Denali/Mt McKinley!—it is nearly impossible to discern climate impacts in the face of such overwhelming anthropogenic disturbance.

A common approach to mountain climate change study is through the protocol of GLORIA sites. While this approach has had demonstrated success, researchers are critically dependant on site selection. There can be some real problems in given locations, but when the number of samples is low, it is critical that each observation be of the highest quality. For example, while I have been here in Nepal, a GLORIA site has been established. The site was in Langtang National Park, where I had just completed fieldwork with 30 students from the Central Department of Botany (CDB) at TU. I thought it particular that they would locate the site where they did, because even a cursory glance at the literature reveals that this area suffers from massive yak overgrazing, due to the location of a cheese factory nearby (Fox et al., 1996; Watanabe, 1994; Yonzon and Hunter, 1991). While the GLORIA team had noted the cheese factory, they had attributed no significance to it and when I asked them how they were assessing grazing impacts, they said they didn't know how and were ignoring it.

Far more importantly, this area is the path of one of the most holy Hindu pilgrimages in the world and tens of thousands of people trek through this site every August. Talking with local people for even a few minutes reveals this fact. These people are coming from the lowlands and use the trek as an opportunity to harvest medicinal and other mountain plants such that nearly all of the

species are removed. So why would a GLORIA site be located in one of the most heavily impacted areas anywhere in the Himalayas? Because the TU personnel suggested it and the researchers who put in the site had flown in just for a week and had no time to personally choose a site. TU takes all foreign scientists to Langtang NP because it is close and thus access is easy, but more importantly, they can bypass the cumbersome process of getting a research permit in this area and the foreign groups never know that they are acting without permission. Having spent many days in government offices trying to get 'official' permission, I understand why TU tries to avoid it if no one is the wiser.

Given the potential problems with a small number of potentially compromised intensive sample sites and given a year of research time, I have adopted a different, extensive, sampling approach. Working with my wife and several TU students per park, I am visiting all of the Himalayan protected areas in Nepal and spending 3-4 weeks in each gathering training samples for remote sensing—characterizing vegetation structure, current species altitude growth limits, species composition, and disturbance levels. Our goal is to gather at least five hundred 20x20 meter sites per protected area. I am demonstrating to the students how to gather this data and then how to use the satellite imagery to create land cover maps measure change through time.

The Central Department of Botany at TU has been gathering botanical data for decades in these areas but the information sits unused in many bound theses in their library. By using past botanical transects collected by CDB with satellite images from the 1970s, 1980s, and more recent decades, we are looking at how vegetation has changed through time in the face of climatic and anthropogenic perturbation. By working with Nepali students who can conduct interviews on ethnobotanical harvesting, grazing, or other extractive uses, we are trying to separate the human from the climate signal. Each student works on a different aspect of a different protected area and we expect at least two PhDs and six Masters to result from this work. More importantly, I am designing this work in such a way that the sites can be accessed through time to directly measure vegetation changes in the future at given intervals.

I hope that such a widespread yet dense series of samples will yield long-term benefits for research in this complex area and that researchers interested in this area will consider collaborations to maximize synergies on Himalayan climate change research.

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An Overview of the Mountain Climate Research Conference MTNCLIM 2010

Melanie Lenart

University of Arizona, Tucson, AZ

EDITOR'S NOTE: *The Consortium for Integrated Climate Research in Western Mountains (CIRMOUNT)—a collaborative, interdisciplinary consortium dedicated to understanding climates and ecosystems of western North America's mountains—held its biennial mountain-climate conference, MtnClim 2010, on June 7–10, 2010 at the HJ Andrews Experimental Forest (HJAF), Blue River, Oregon. Some 90 scientists and students from USA, Canada, and Europe attended the conference. The principal themes for the meeting included invited sessions on high-resolution climate monitoring and modeling; perception of climate risks; communicating scientific uncertainty in the context of decision support, and contributed sessions.*

Scientists examined the fine-scale details of the ongoing climate change at the three-day Mountain Climate conference, held in June against the backdrop of Oregon's old-growth conifer forest. Like the U.S. West as a whole, the temperature rise at higher elevations generally seems to be exceeding the global average, as some participants indicated.

Natural-resource managers, such as our hosts at the HJ Andrews NF, recognize that on-the-ground effects to plants and animals occur in a complex interplay of ongoing weather events rather than in immediate consequence of long-term changes in average temperature. As if to emphasize this point, the conference took place during an unusually rainy and cool second week in June.

On the other hand, as participants emphasized, these global changes are likely to drive extensive changes across the landscape that could shift climate zones and, thus, habitat niches in complex ways that remain difficult to predict. Many drew upon research in the Andrews forest to illustrate the complexity of climate change as it manifests in mountainous regions.

Climate

Climate Change in Action

The temperature rise that defines climate change appears to be re-establishing itself with vigor this year at the global scale, a shift that could help put to rest arguments by climate change skeptics who have used recent U.S. weather to fan doubts about global warming.

Combined January through April temperatures globally were as high as during the first four months of the record-breaking heat of 1998, climatologist Kelly Redmond of the Desert Research In-

stitute told the MTCLIM group. Other observations also suggest global temperatures are on the upswing again this year.

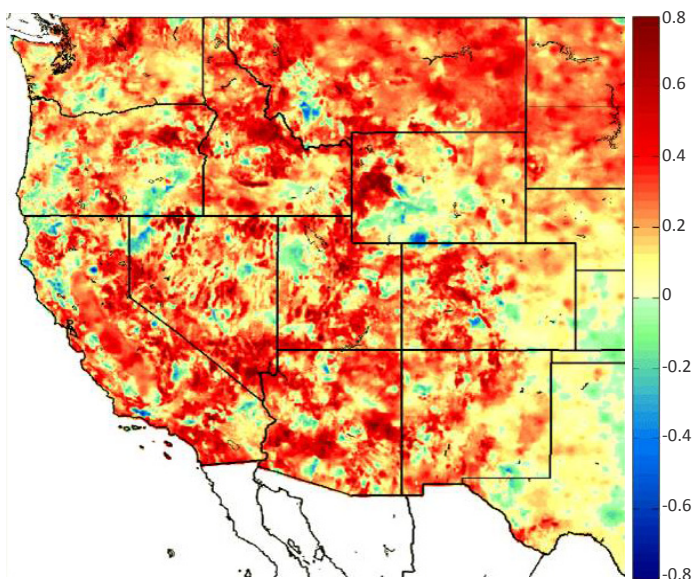
"I think we're going to be hearing about Greenland this summer," said Redmond, noting Arctic sea ice extent in mid-May had shrunk to record levels for that time of year. It was even lower than in mid-May of 2007, before a summer when so much Arctic ice melted that ships could pass through the Northwest Passage for the first time in recorded history.

Things cooled off slightly in the two years following 2007. Some climate skeptics have pointed to the years 2008 and 2009, as well as winter storms that brought snow to 49 of the 50 U.S. states in February of 2010, as reason to doubt the well-established evidence that climate is changing. However, even those years ranked among the World Meteorological Society's top 10 hottest years in its 150-year instrumental record.

"If you want to know what's going on around the globe, you can't necessarily tell by just looking out your window at your local spot," Redmond reminded. He showed temperature results from 30 years of satellite records to make the point. "Actually, when all those big snowstorms were hitting the East Coast and the Southeastern United States, it was actually the warmest the Earth has been in the last 30 years and probably – since that's a warm part of the record – probably back beyond that."

While the average temperature of the globe defines the changing climate, it has little to say about how the ongoing changes will manifest – and what it means for species – at the finer scale of the landscape where resource managers operate, participants agreed.

Redmond illustrated this with a comparison of recent temperature changes around the West. Global climate model results generally



The map above, created by John Abatzoglou of the University of Idaho using PRISM data, shows the linear trend of annual minimum (nighttime) temperatures in degrees Celsius per decade for the period from 1950 to 2008. This preliminary analysis uses the version of PRISM with a 4-kilometer grid size.

paint the western half of the country red to represent projected increases in temperature. Yet the end result is much more likely to be as complex as western topography, he noted, illustrating his point with complex maps of the warming of the past few decades.

The maps, created by John Abatzoglou based on the PRISM approach designed by Christopher Daly and colleagues at Oregon State University, showed pockets of yellow and blue highlighting areas of little warming or even cooling amid the overall red-hot warming.

PRISM Helps with Fine Scale

Many MTCLIM speakers, including Daly, used the PRISM approach to help illustrate fine-scale changes on the landscape.

Daly, a longtime researcher associated with Oregon State University at Corvallis, used the detailed climate measurements from the H.J. Andrews Forest to identify how changes occur across the landscape. He used this information along with data from other networks to develop monthly temperature and precipitation estimates across the United States on grids that measure 800 meters on a side, or about 150 acres per pixel.

As in the Andrews forest, the climatic changes that occur as one moves across the pocked western landscape depends on many factors. PRISM considers effects from slope, aspect, location in relation to mountains, and proximity to coast, among other factors influencing temperature and precipitation.

PRISM equations attempt to account for the complexities and contradictions inherent in the landscape. For instance, it adjusts for the orographic effect, i.e. the tendency for mountains to provoke precipitation as they lift clouds into cooler realms. It also adjusts for the rainshadow effect of drier conditions downwind of mountains, as air depleted of moisture descends onto the landscape.

Meanwhile, moisture tends to modify potential temperature swings. When available during the day, it provides fodder for evaporation, which uses up some of the solar power that could otherwise warm the air. At night, water vapor acts as a greenhouse gas, blocking some of the local heat from escaping into space.

The higher air moisture levels and thermal mass of the oceans around coasts help to moderate temperature swings, but only on the seaward side of mountain ranges, Daly pointed out. Using the California coast as an example, he showed how some mountains hug the coast, shortening moisture's temperature-modifying effect to a sliver of land.

PRISM also considers two contradictory tendencies mountains can have on temperature. Typically, temperature tends to decrease with elevation. Yet cold air can "drain" into low spots on the landscape, like water flowing into a depression, making some valleys much colder than surrounding slopes.

"We were sitting in a cold air pool this morning – I'm sure you felt it," Daly told the group in a Tuesday session. The foggy chill around the Andrews headquarters put temperatures at about 43



The HJ Andrews Station array of climate sensors. Photo by Melanie Lenart.

degrees Fahrenheit on that June 8 morning. Many winter days in Oregon suffer from this effect.

Nighttime minimum temperatures are rising faster overall than daytime maximums in the West, a finding of Daly's that was echoed by several other participants. Daly indicated that, in the data set he's using, it's not yet clear whether temperatures in the mountains are rising faster than the global average. Elsewhere in the world, however, there were indications they might be.

It's the Humidity

The Tibetan Plateau has one of the highest rates of warming in the northern hemisphere, with the warming greatest at the higher elevations, noted Jim Miller of Rutgers University in New Jersey. Also, winter is warming more than summer across the plateau.

Melting sea ice in the Arctic Ocean promotes warming because water absorbs far more heat than ice does. But melting sea ice can't explain the greatest warming in the winter because ice extent remains stable during winter.

"So what causes that enhanced temperature in the winter?" Miller asked. "Other factors. We believe that one of those is an increase in water vapor. We also have some evidence that clouds have increased as well. So clouds are part of this."

Water vapor is the world's most prevalent greenhouse gas. And the amount of water vapor in the air has increased globally, as air holds more moisture as it warms.

Meanwhile, the heat-trapping power of water vapor increases most dramatically where the amount of water vapor in the atmosphere starts out low – as it does around the Tibetan Plateau in winter.

Water vapor's heat-trapping effect can be several times more extreme in winter than in summer. For example, Miller showed results from preliminary modeling experiments by fellow MTCLIM participant Imtiaz Rangwala that suggested that adding 0.4 grams of water vapor per kilogram of air at the atmosphere's boundary layer would add more than 5 watts per square meter of extra heating at a high-elevation Tibetan Plateau site in winter, while barely bumping it up by about 1 watt per square meter in summer and at low elevations.

Preliminary work suggests Colorado's San Juan Mountains may be facing a similar situation. The San Juan's also have been registering a large nighttime warming in recent decades, and Miller showed data from two sites that suggest water vapor could also be playing a role.



Typical day at HJA during the MTNCLIM 2010 Conference. Photo by Melanie Lenart.

Gaining a greater understanding about the roles played by both water vapor and clouds are key to efforts to improve climate model projections, he said.

"Water both impacts climate change and is impacted by climate change," Miller reminded. "In some ways, clouds are still the biggest unknown in climate change."

Ecosystems

As in the H.J. Andrews forest, mountain regions around the world serve as microcosms for the study of the ecological impacts of climate change. MTCLIM speakers explored that variability in a variety of creative ways at both large and small scales.

While models remain the most common way of testing how species will fare under climate change conditions projected for the future, some researchers were using what Phillip van Mantgem called "boots-on-the-ground" observations to consider how ecosystems are changing as a means of assessing potential future changes.

Changes in slope and aspect across the landscape can result in significant differences in microclimate, as described in the climate section. Often, this fine-scale variability produces temperature differences greater than the several degrees Celsius increase projected for the planet as a whole.

Stuart Weiss, for example, showed that near-ground temperatures in California's White Mountains consistently vary by about 8

degrees Celsius within a single square kilometer. These changes in both daytime maximum and nighttime minimum temperatures appear to affect where bristlecone pines can grow, based on research he has conducted with colleagues. Weiss calls these fine-scale changes “topoclimate.”

Temperatures of the ground surface itself, where crawling insects dwell, can be even more extreme. His research found that noon surface temperatures in California serpentine grasslands – habitat for the caterpillars that turn into a threatened species, Bay checkerspot butterflies – ranged from 10 degrees Celsius on north-facing slopes to 40 degrees Celsius on south-facing slopes only a few dozen meters away.

For checkerspot caterpillars, these differences can shift survival rates, which fluctuate widely from year to year. While caterpillars sunning along south-facing slopes can grow faster, they also run the risk of seeing the vegetation within their reach dry out – something that warming temperatures can speed up – before they are ready to transform into butterflies with enough mobility to seek out suitable microclimates for themselves.

At any rate, the ongoing temperature rise appears to be initiating a variety of impacts on the nation’s forests.

More Deaths in Old Growth

Van Mantgem and his colleagues found mortality rates have been rising in old-growth western conifer forests since about the 1970s. They compared census measurements for 76 sites of old-growth forest, including the H.J. Andrews and many others in the Pacific Northwest, restricting their analysis to undisturbed forests more than 200 years old. Most of them were dominated by spruce, fir or pine trees.

“We’re declining in density and basal area – and that means we’re slowly leaking carbon,” van Mantgem told the group, referring to the carbon stored aboveground in vegetation. As part of the Willamette National Forest, H.J. Andrews tops the nation for the amount of carbon stored in trees and soil, noted speaker Rebecca Kennedy, citing a March 2010 Wilderness Society report. Dry wood is typically half carbon, all of it converted from the greenhouse gas carbon dioxide. When trees die, some of that carbon transforms back into carbon dioxide to resume warming the planet.

While mortality increased in about 87 percent of the plots van Mantgem and his colleagues considered, recruitment increased in only 52 percent of plots. The reason for the increased mortality remains undefined, but they ruled out increased stand density

and fire regime, among other possibilities. As van Mantgem pointed out during his talk, this leaves the large-scale temperature increases and related lengthening of the summer drought as likely candidates.

Mortality rates varied depending on various factors they tested, as he and his colleagues reported in a 2009 Science paper. For forests above 2,000 meters, it ranged from about 0.3% in the early 1970s to nearly 1% in recent years. In lower elevations, mortality rates rose from about 0.3% to about 1.5% in recent decades.

Mortality rates in temperate coniferous forests around the globe averaged 0.77% in a 2005 Ecological Letters paper led by Nathan Stephenson, who was lead co-author on the 2009 paper with van Mantgem and others. The 2005 paper also examined mortality rates in coniferous forests in California’s Sierra Nevada Mountains and found it was highest in lower elevations. Globally, mortality rates were highest in the most productive forests.

Stephenson cautioned that the earlier results were not directly comparable to the new study, as plots and measurements techniques differed. Also, while the earlier study found mortality and recruitment rates were roughly the same, their 2009 paper found mortality rates generally outpaced recruitment rates.

In a similar approach focused on the Sierra Nevada Mountains of California, Christopher Dolanc, a graduate student at the University of California-Davis, resampled 139 plots at high elevations between Yosemite and Lake Tahoe that had initially been surveyed during the Depression of the 1930s.

Dolanc found a consistent increase in the number of small trees (between 10 and 30 centimeters in diameter), coupled with a consistent decline in the number of big trees (above 60 centimeters).

While old-growth sites were showing a recent increase in mortality in van Mantgem’s study, tree-ring data for Douglas fir trees for Oregon as a whole suggest a mixed response to warming temperatures, Julia Jones of Oregon State University explained during a talk focused on the Andrews forest.

The Doug fir growing at higher elevations tended to grow better during years of warmer temperatures, which typically occur during drier years. Meanwhile, those at lower elevations grew faster when summer moisture was high, she noted, referring in both cases to tree-ring research by Brian Black. “These (results) tend to suggest that perhaps some of the reasons that we’re not seeing more hydrological response to changes in climate is that the trees, the Douglas fir dominants, have been able to adjust their growth rates, and to some extent their water use, in response to the

change in climate,” she added.

Greenness Increasing

The increased mortality in old-growth forests and loss of large trees detected in studies by van Mantgem and Dolanc, respectively, contrasts with an overall increase in greenness found throughout the West by Louis Scuderi of the University of New Mexico. He used the Global Production Efficiency Model to consider results of about 30 years of satellite data on “greenness,” often used as a proxy for Net Primary Productivity (NPP).

Although scientists often use greenness and NPP interchangeably because they are highly correlated, Scuderi agreed with Stephenson’s suggestion after his talk that the word “greenness” better describes the results. While satellite records do well at measuring the amount of growth occurring – i.e., greenness – they cannot detect changes in the amount of deadwood on the ground. If more trees are dying, more carbon could be released even if remaining trees thrive and register an overall increase in greenness. Also, Stephenson noted later that NPP and greenness do not correlate well in all forests.

Greenness increased by about 7 percent overall between 1981 and 2000 throughout the West, with exceptions including the Yellowstone Park area, which Scuderi suggested might relate to the large wildfire in 1988. Averaged over the West, the changes amounted to an increase in NPP of about 67 grams of carbon per square meter, he noted. He said he was seeing similar results in a preliminary analysis of Modis satellite data for the 2000s.

Scuderi said he was inspired to undertake the analysis following a long conversation with climate change skeptic Steve McIntyre, founder of the blog Climate Audit. McIntyre’s skepticism about a reported growth increase in foxtail pine as measured by annual tree rings led Scuderi to explore vegetation growth trends using an independent method.

After comparing his results to a species distribution map, Scuderi concluded that the greatest increases in greenness occurred where slow-growing, drought-tolerant species thrived.

The bristlecone and foxtail pines favored for developing lengthy tree-ring chronologies of temperature generally fall into this category. They grow slowly – but potentially do so for thousands of years, making them excellent natural archives of changing climate conditions. Thus, Scuderi said, his work refutes some of McIntyre’s concerns about the tree-ring studies suggesting that recent temperature increases are unusual. Based on his indepen-

dent analysis, climate change does appear to be boosting annual growth rates.

Extreme Events

While climate models do best at predicting average conditions, it’s the extreme events that typically create havoc for society. Several MTCLIM speakers addressed the issues of understanding extremes – and helping decision makers plan for them.

Floods, droughts, hurricanes and heat waves are all expected to get more extreme as the planet heats up. Trying to predict these events – a recurring request by decision makers and other stakeholders – is challenging yet important for planning purposes.

Several speakers labeled these extremes as “black swan events,” alluding to the 2007 book *The Black Swan* by Nassim Taleb, which describes how highly improbable events with massive impact often shape the world. Floods and sediment movement illustrated this concept at the Oregon meeting.

Atmospheric Rivers

Many of the extreme floods that submerge western landscapes, such as the 30 inches of rainfall that deluged Oregon and Washington in the autumn of 2006, trace back to what Paul Neiman of NOAA’s Earth System Research Laboratory called “atmospheric rivers.”

These airstreams of enhanced moisture occur in relatively narrow bands comprising only about 10 percent of the total area of the atmosphere at midlatitudes, he noted, adding that most of the plumes affecting the West occur around the jetstream on the warm side of cold fronts.

“Clearly atmospheric rivers are associated with rather warm conditions at these low levels,” he noted, after showing a composition of typical climatic conditions for the presence of atmospheric rivers flowing over the Pacific Northwest coast during December through February.

They’re also associated with floods. Using satellite imagery to identify atmospheric rivers, Neiman found that 46 of the 48 highest streamflows in a 12-year record for four sites in the state of Washington occurred when atmospheric rivers made landfall.

A California study took atmospheric rivers into consideration when responding to a request to simulate an extreme winter storm scenario that would challenge local emergency responders.

Future Floods

Mike Dettinger, a researcher with the U.S. Geological Survey and Scripps Institute of Oceanography, worked with Marty Ralph of NOAA to simulate a realistic storm sequence that left Los Angeles inundated and the Central Basin “pretty hammered.” “It still amazes me how little we had to tweak things in order to make kind of a monster storm,” Dettinger told the MTCLIM group in his report on the project, known as ARkStorm.

He and Ralph created the simulation by combining two historical warm winter storms: a February 1986 storm in northern California and a January 1969 storm in southern California. They also added an extra day of stalling over Los Angeles at the peak of the latter.

Although the results of these “bucketloads” of rainfall look extreme to some stakeholders, and the impacts remain subject to re-evaluation before the planned release of a USGS report in late summer, the levels of rainfall are quite plausible, Dettinger said. He noted that the impacts from an infamous 1862 storm were about as bad as from the simulated storm.

The floods from the 1862 storm buried the Los Angeles basin in water and inundated the Central Valley in a corridor that ranged from 12 to 60 miles wide across a 300-mile stretch. The storms behind the flood started on December 24 of 1861 and lingered through January 21 of 1862, with only 12 days separating the flood crests in Sacramento and Los Angeles.

“It remains in the public eye as The Big One for storms,” Dettinger said.

Big Floods Move Mountainsides

These big events are the ones that shape the landscape, noted Bodo Bookhagen of the University of California at Santa Barbara. His work in the Himalayan Mountains indicates that scientists cannot expect to find the full range of extremes in an instrumental record that, at best, goes back to 1895 in the West.

“Even if we have a 100-year record in the western United States, that is not long enough to capture these extreme events,” Bookhagen pointed out. “So we need to look into different archives to understand the extreme events that are the landscape-shaping processes.”

In his measurements over a five-year period, he found that half the sediment carried in a local river in the Himalayas came from two big events.

Other studies, too, have found that it’s the big floods that shift

the most sediment around a landscape. Mountains are a major source of sediment, as their steep slopes and tendency to produce landslides during heavy rains bolster erosion rates.

Even the big storms Bookhagen assessed in the modern record pale in comparison to other land-shaping events in the sediment record, he said. At the 30-year time scale of measurements, the erosion rate averaged out to about 1 millimeter a year. Yet at the 300-year time scale as derived from sediment records, the erosion rate was about 2.8 millimeters a year, nearly three times higher. He noted that erosion rates climbed to 4.3 millimeters a year from 5,000 to 7,000 years ago during an intensified phase of the Asian Monsoon.

“I think we have learned this morning that it is quite difficult to establish a record of extreme events with climate models,” Bookhagen said. “Instead of emphasizing climate models that predict the future, we need to look into the past geologic record. This would ... give us a better range of the extreme events, and therefore we are able to predict what would happen in the future better.”

Risk Assessment

Water managers and other stakeholders are looking for plausible climate change scenarios – but they want to see an approach that can lead to positive action, not scenarios that make them feel helpless.

That was a general conclusion of two separate efforts, one by Gregg Garfin of the University of Arizona’s Institute of the Environment and another by Michelle Wood of California State University.

“Fear is not a great motivator – and we’re hearing that from water managers in a big way,” Garfin reported to MTCLIM participants.

A Plausible Range

Managers are seeking information about plausible futures, rather than a precise but potentially inaccurate prediction, when considering how to build resilience into their infrastructure, he said. That was a key point made in recent efforts by Garfin and his colleagues to help water managers assess climate impacts on central Arizona surface water.

Also important was getting information from “the horse’s mouth,” in this case expert climate modeler Linda Mearns, Garfin reported. Mearns spoke at separate workshops for both the

water managers and a climate change initiative focusing on land management across multiple jurisdictions. Participants indicated they appreciated getting an insider's view of the state of climate modeling.

At the same time, water managers did not want to be restricted to considering only a drought-based future for water resources, Garfin noted, even though most climate models project reduced flow in rivers as air temperatures rise and evaporation takes an additional toll on water resources.

"They want wetter hydrology to test their assumptions about their reservoirs," he said.

Positive Messaging

Like Garfin, Michelle Wood found that fear does not do the trick when it comes to convincing people to take action about a perceived risk.

Wood reviewed the literature of research from the past 50 years and analyzed national survey data about household preparedness. She reported her findings in the context of how to convey information to convince people that they should take action on climate change.

The analysis she conducted with others found the most effective campaigns explained to people what actions to take and how these actions would cut losses – and did so in a way that was consistent across all messages.

Extended informational campaigns that use a variety of different mediums to convey the message worked best at getting people to take action, Wood said. Increasing knowledge, increasing the perception that the action was going to be effective, and getting people to talk to others were among the best ways to get people to take action. Seeing other people take actions was another effective motivator, she said.

"Fear doesn't really get people to do things," she said, noting that perceived risk tends to fall out of the models once other factors are taken into consideration. Ironically, efforts to instill fear are a standard approach for attempting to convince people to take action, from conveying the dangers of using methamphetamine to the risks of the ongoing climate change.

Wood recommended the following steps for communicating risk:

1. Use evidence-based approaches
2. Stop doing things that don't work
3. Use multiple information sources

4. Brand the message, not the messenger
5. Use multiple information channels
6. Communicate over the long haul
7. Focus information on actions they can take
8. Explain the beneficial consequences of the recommended actions
9. Convey what other people have done
10. Encourage people to talk to each other about preparation

"We basically flipped our perspective upside-down," Wood said. "We went from communicating risk so that people would infer, 'Gosh, I better do something about this to get ready,' to communicating actions that people should take, whereby they would then infer, 'Gosh, I must be at risk.' So it's a different perspective."

The session on risk communication was called the Machida session in honor of Dennis Machida, an environmental lawyer who passed away during a MTCLIM session in 2005.

Greg Greenwood gave an update about some of the ideas that Machida had planned to talk about based on his notes. Both Greenwood's 2010 talk and Machida's notes from his 2005 talk are posted on the CIRMOUNT website along with other talks given over the years: <http://www.fs.fed.us/psw/mtnclim/talks/>.

*Melanie Lenart is an environmental scientist and writer affiliated with the University of Arizona. She is the author of the 2010 book *Life in the Hothouse: How a Living Planet Survives Climate Change* (University of Arizona Press).*

Announcements

CIRMOUNT Session at AGU 2010 Fall Meeting

December 17, 2010, San Francisco, California. Both oral and poster sessions of the CIRMOUNT GC-28 session, "Ecosystem Responses to Fine-Scale Climate Variability in Mountainous Terrain", will be held on this date. Visit: <http://www.agu.org/meetings/fm10/>. Contact: Connie Millar (USFS), cmillar@fs.fed.us.

Global Change and the World's Mountains

September 26-30, 2010, Perth, Scotland. For information, contact Mountain Research Institute Director, Greg Greenwood, or visit: <http://www.perth.ac.uk/specialistcentres/cms/Conferences/Perth2010/>.

