

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

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Table of Contents

The Mountain Views Newsletter	Henry Diaz and Connie Millar on behalf of CIRMOUNT	1
The MRI and CIRMOUNT—A Lofty Symbiosis?	Gregory B. Greenwood	2
Re-Framing Forest and Resource Management Strategies for a Climate Change Context	Connie Millar, Nate Stephenson, and Scott Stephens	5
Monitoring the Pulse of our Planet—The USA-National Phenological Network (USA-NPN)	Mark Losleben and Jake Weltzin	11
Adapting to Climate Change on Olympic National Forest	Dave Peterson, Jeremy Littell, and Kathy O’Halloran	15
Taking the Pulse of Mountain Forests: The Cordillera Forest Dynamics Network (CORFOR)	Nathan L. Stephenson and Alvaro J. Duque	18
Forest Disease Conditions and Climate: What’s Changed?	Susan J. Frankel	21
Announcements		24
• MntClim 2008		
• Fifth WMRS Regional Research Symposium: Climate, Ecosystems, and Resources in Eastern California		

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Front Cover Photo: Silverton, CO after a heavy blanket of snow. Credit: Center for Snow and Avalanche Studies, Courtesy of Chris Landry

Back Cover Photos: Winter (top) and Summer (bottom) views of monitoring station in the Senator Beck Basin site, San Juan Mountains, Colorado. Photos Credit: Center for Snow and Avalanche Studies, Courtesy of Chris Landry

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The Mountain Views Newsletter

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With our third issue of the Mountain Views Newsletter (MVN), we begin our second year of publication. We are very pleased with the reception that this communication vehicle has received from our colleagues in the greater mountain climate sciences community. The climate of the West is changing—and changing rapidly. The region now finds itself in the midst of nearly-decade-long drought, as severe as any that has been experienced in the century-long observational record. The Consortium for Integrated Climate Research in Western Mountains (CIRMOUNT) was formed to provide a unified voice for the climate science community to communicate concerns and promote public awareness of the serious problems arising from a changing climate and its interactions with human and natural systems in the region. Readers are encouraged to log-on to our website: <http://www.fs.fed.us/psw/cirmount/>.

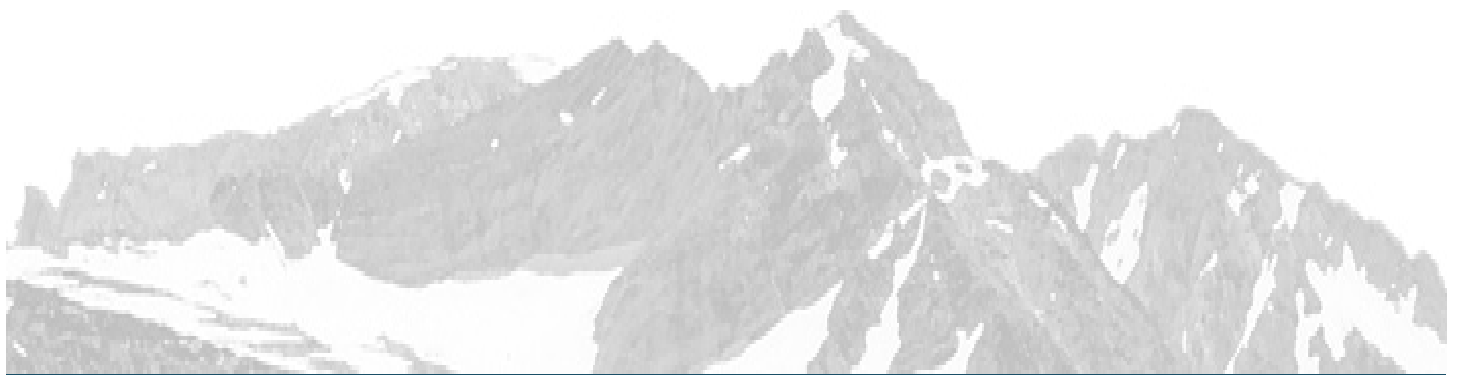
As has been noted in previous issues, the Newsletter is meant to be a clearinghouse for information about recent developments in the field, including summaries of new findings about the state of regional and larger-scale climate patterns, and related environmental and ecological-science activities bearing on western North American society.

This third issue of MVN highlights important activities related to climatic changes in mountain regions at regional to international levels that are needed to enhance information about the adaptive capacity of natural systems in the face of such changes. For example, Greg Greenwood discusses the strong relationship between the Mountain Research Initiative (MRI), administered through the University of Bern, Switzerland, and CIRMOUNT. Specifically, he discusses an agenda for action that would help our community to implement some of the policy pronouncements

found in a number of previous “climate change and mountains” documents. Millar, Stephenson, and Stephens consider some useful strategies needed to incorporate climate change in forest resources management decision-making. In this same vein, Peterson, Littell, and O’Halloran discuss some adaptation strategies as they pertain to the Olympic National Forest in Washington State, and the article by Stephenson and Duque describes a developing effort—with the help of the Mountain Research Initiative—to establish a network of long-term forest plot monitoring sites under the name of CORFOR (The Cordillera Forest Dynamics Network) along the American Cordillera. Losleben and Weltzin describe important elements associated with the recently launched US National Phenological Network. Finally, Susan Frankel highlights some issues related to forest diseases and climatic change.

We are also pleased to bring to the attention of our readership the convening of the Mountain Climate Conference—MtnClim 2008—that will be held in Silverton, Colorado on June 9–12, 2008. Readers can get information by login onto the CIRMOUNT website, or to the workshop site at: <http://www.fs.fed.us/psw/mtnclim/>.

As we have noted previously, we welcome contributions from readers on subject matters such as have been presented in this and previous issues of the Newsletter. Examples include contributions on scientific aspects of climatic variations and change and on past, emerging and potential future impacts of those changes on the management of water, forest, and ecosystem resources, and on studies of the ongoing demographic changes in the region as they interact with changes in climate.



The MRI and CIRMOUNT—A Lofty Symbiosis?

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The website of the Consortium for Integrated Climate Research in Western Mountains (CIRMOUNT) and its foundational documents make several references to the Mountain Research Initiative (MRI). The MRI website contains presentations recorded at all of the MTNCLIM Workshops, and the MRI Director frequently appears at CIRMOUNT functions. But beyond these tactical relationships, what is the function of the MRI? What are its origins and what can MRI and CIRMOUNT do for each other?

The Entwined Histories of the MRI and CIRMOUNT

Recognizing the significance of mountain regions for global change research, the International Geosphere and Biosphere Program (IGBP) together with the System for Analysis, Research and Training (START), organized a workshop in Kathmandu, Nepal (March/April 1996), which resulted in IGBP Report 43: “Predicting Global Change Impacts on Mountain Hydrology and Ecology”.

Immediately after the workshop, the results were discussed in a special session at the first IGBP Congress held at Bad Münstereifel, Germany, 18–22 April 1996, which was attended by members of the Scientific Steering Committees (SSCs) and representatives of the IGBP core projects and by the IGBP Secretariat, in particular the IGBP Executive Director. The representatives of Land Use and Cover Change (LUCC) and Past Global Changes (PAGES) projects enthusiastically expressed an interest to participate in the further development of the initiative.

The reports from other related meetings, together with IGBP Report #43, served as the basis for developing a draft foundational document for this Initiative on Global Change and Mountain Regions at a joint IGBP/International Human Dimension Program (IHDP) workshop in Pontresina, Switzerland on 16–18 April 1998. Fifteen experts attended the workshop, sponsored by the Swiss Academy of Natural Sciences. The participants of the Pontresina workshop emphasized the need for interdisciplinary global environmental change research, involving both natural and social scientists, to support sustainable development in mountain regions. The emphasis on an encompassing interdisciplinarity in a place-based context distinguishes the MRI program from more traditional global change programs such as the Global

Carbon Project.

MRI’s foundational document, *Global Change and Mountain Regions: The Mountain Research Initiative*, (IGBP Report 49) appeared as a joint IGBP, IHDP and Global Terrestrial Observation System (GTOS) report in 2001. It proposed a research framework expressed in terms of scientific activities consisting of:

1. Long-term monitoring and analysis of indicators of environmental change in mountain regions
2. Integrated model-based studies of environmental change in different mountain regions
3. Process studies along altitudinal gradients and in associated headwater basins
4. Sustainable land use and natural resource management

The report is available on the MRI website at <http://mri.scnatweb.ch/content/view/75/54/>

A quick comparison of IGBP Report 49 and CIRMOUNT’s Mapping New Terrain [http://www.fs.fed.us/psw/cirmount/publications/pdf/new_terrain.pdf] shows that MRI and CIRMOUNT occupy very similar institutional niches. A principal difference is that MRI has a budget and a staff, and consequently a program that is focused on communication, influencing funding, and perhaps most important, active involvement in the formulation of research programs and submission to funding agencies.

One initial effort of the Mountain Research Initiative to translate the scientific framework expressed in the foundational report into operational plans was a workshop on Global Change Research in Mountain Biosphere Reserves held in the Entlebuch Biosphere Reserve, Switzerland on November 9–13, 2003. Among the participants in the Entlebuch workshop were Connie Millar, Dan Fagre, Jill Baron, Bill Bowman, Ray Bradley, Doug Hardy, George Malanson, and Hans Schreier, names familiar to those in CIRMOUNT.

Not long thereafter, on May 25–27, 2004 CIRMOUNT was launched at the Mountain Climate Science Symposium held in Kings Beach, Lake Tahoe, California [Diaz and Millar, 2004]. Among the invited participants were key European scientists present at Entlebuch: Bruno Messerli, Georg Grabherr, Harald

Pauli, and Harald Bugmann. Thus the two programs, MRI and CIRMOUNT, arising from an International/European and an American context respectively, crossed paths in 2003 and 2004, and have been orbiting each other ever since.

What can MRI and CIRMOUNT do for each other?

The vision of the MRI Coordination Office is

more research projects congruent with the global change research strategy outlined in IGBP Report 49 and further refined in the Global Change in Mountain Regions (GLOCHAMORE) Research Strategy. (See <http://mri.scnatweb.ch/content/category/3/10/30/> for more information on the GLOCHAMORE project).

There are at least three ways to convene researchers around the task of developing new global change research programs for mountains. One could organize researchers around *modes of scientific activity* such as the Group on Earth Observation (GEO) is attempting to do for observations. Both MRI and CIRMOUNT espouse better observation systems, and hence a focus on new observation projects that fill critical monitoring gaps is appropriate. One could also organize researchers around *research topics*, such as those highlighted in the GLOCHAMORE strategy. For instance alpine community change has been a very compelling basis for the GLORIA project, largely because of its focus. Or one could organize researchers around *places or mountain ranges*, such as the American Cordillera, or Africa. In truth all three perspectives resonate with different parts of the research community and each contains aspect of the other two. Therefore all three are potentially useful in organizing collaborative proposals. MRI has emphasized the integrative paradigm, and has promoted the notion of regional global change research networks in mountains (GCRNs), consisting of researchers and research sites within a region, all working on those parts of the GLOCHAMORE strategy that are most compelling within that region.

The notion of a regional global change research network, guided by the GLOCHAMORE strategy, and encompassing different disciplines and nationalities is admittedly an ideal-type but nonetheless seems to have some traction in the real world. Since 2006, MRI has held several workshops mobilizing a global change research network for European mountains (<http://mri.scnatweb.ch/content/category/3/47/68/>). This organizational effort culminated in a Research Network Program proposal to the European Science Foundation in October 2007 to develop a

network investigating integrated assessment methodologies for hydrologic, ecologic catchment processes in European mountains under global change. While it is unknown at this point if the proposal will be funded, the proposal is already a success in that partners from more than 20 European countries participated in the proposal. Similarly, a group of African researchers convened in Kampala in July 2007 is developing a global change research network for African mountains with its flagship project being the development of high elevation observation network. And finally, though MRI had nothing to do with its creation, the Western Mountain Initiative (WMI) of the USGS looks and acts very much like a regional global change research network for the Western USA.

The American Cordillera Transect is a regional global change research network for North and South America launched by the MRI at the CONCORD meeting in Mendoza, Argentina in 2006 [Diaz et al., 2006]. The MRI envisions a network of researchers associated with sites along the Cordillera who are simultaneously working across disciplines at their sites as well as across sites with their disciplinary colleagues in other countries.

In this context, MRI views CIRMOUNT as an important ally in developing the American Cordillera Transect. One policy action and several follow up activities by CIRMOUNT could be helpful.

The policy action consists of CIRMOUNT endorsing the establishment of the American Cordillera Transect as a major means by which to achieve the goals it enumerated in Mapping New Terrain: monitoring, integrated research, communication, data and international involvement. Accepting involvement in the creation of such a network provides one answer to a question that has vexed CIRMOUNT for some time: what, beyond conferences, can it do to achieve its goals?

Policy pronouncements only become useful to the extent that they induce action, and at least two actions would be helpful in this case. The first would consist of assessments of: 1) the degree to which the WMI meets the criteria of a GCRN; 2) the relative significance of any differences that might exist between the WMI and the concept of GCRN; and 3) the options and feasibility for closing any gaps. The underlying premise of these actions is that the WMI is for all intents and purposes a proto-GCRN in the Western US. Furthermore, it seems likely that the WMI constitutes an excellent core around which one could array, in geographic, disciplinary and institutional space, other research projects to achieve the vision of a GCRN. The activity is a

CIRMOUNT, rather than an exclusively USGS activity, exactly because expanding WMI in geographic, disciplinary and institutional spaces necessarily involves many more organizations than just the USGS.

The second action would involve the establishment of collaborative relationships and projects with other researchers and sites along the American Cordillera that, taken together, would approximate that which we want to see with the American Cordillera Transect. Such relationships are being developed around specific themes involving forest change and forest dieback, and could be extended to other themes as well. They could as well be developed around monitoring and observation networks, a work-group activity within CIRMOUNT and an opportunity that was recognized in Mendoza but unfortunately never pursued. Such an effort could involve the invitation of several sites outside the US to join in the investigations of the WMI. For instance, it is not difficult to imagine WMI watershed questions being studied in Huascarán National Park in Peru, or WMI forest ecology themes being pursued in the forests of central and southern Chile.

It is always difficult to move from the easy conceptual gener-

alities such as those in the preceding paragraphs to the specific projects and budgets that any real version of the American Cordillera Transect will require. For this reason, MRI is sponsoring a joint event at MTNCLIM III to discuss with interested participants how best to create these relationships and projects. In addition, the MRI is pleased to announce that Dr. Fausto Sarmiento, a geographer at the University of Georgia (Athens) has agreed to serve as coordinator of the American Cordillera Transect in 2008. MRI hopes that these management contributions will be sufficient to catalyze North American participation in the American Cordillera Transect.

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Re-Framing Forest and Resource Management Strategies for a Climate Change Context

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Introduction

Among the surprising developments during the 2007 year-of-climate-dawning was an abrupt change in the nature of dialog between scientists and natural-resource managers. In previous years the primary communication involved researchers talking with managers about climate change and its impacts on ecosystems. By early 2007 the significance of climate became widely embraced, and the conversation did an about-face. From national agency headquarters to local field offices, the collective voice of decision-makers echoed resoundingly back to science: “OK, we get that climate is important. Now, what do we do about it?” That question initially silenced many in the research community, although serious efforts have been investigating resource management implications for some years (e.g., Dale et al. 2001, Spittlehouse and Stewart 2003, Willows and Connell 2003, Joyce et al. 2007a). While field-proven conceptual frameworks and desktop manuals will be developed only through collaborative efforts of scientists and managers, we offer the following as an overarching framework of options for addressing climate change issues in resource contexts such as encountered in western mountain environments (Millar et al. 2007, Joyce et al., in press).

Defining Assumptions

- *Embrace and work with change.* While this may seem obvious, many existing resource-management practices rest on assumptions that ecological backgrounds are stable over time even though they acknowledge short-term successional dynamics. Likewise, engrained institutional traditions commonly rest implicitly on assumptions of persistent and stable behavior. Make friends with change, while still working to mitigate it.
- *Accept uncertainty as a premise for decision-making.* While opportunities for prediction and forecasting will be presented to managers, uncertainty will always lurk close at our shoulders—at least at the scale relevant to most resource-management projects. Addressing uncertainty head-on will often

be more effective than taking a course of action based on a narrowly defined future. For many situations, we will never have enough knowledge to predict future outcomes at scales that matter to managers. Evaluate the wisdom of “putting your eggs in one basket” (accepting a definite future) versus “hedging your bets” (accepting uncertainty) strategies.

- *Recognize that some existing management paradigms have limited value.* This is because many traditional practices are based on assumptions that the past will be similar to the future—that ecosystems are not changing over time. Climate change puts that notion finally to bed. Many ecosystem-management philosophies will still make sense, especially when practiced creatively. This is a good time to experiment with old techniques in new ways and pioneer altogether novel approaches.
- *Manage for desired future processes rather than desired future conditions.* Composition and structure relate to static rather than dynamic goals; a focus on ecosystem services and ecological and physical functions as management targets fixes the aim on dynamic process.

Overall Strategy: Adopt a Toolbox Approach

No single solution and no individual management approach will be appropriate to all or even most situations. The diversity of resource contexts has always required that place-based and individualized prescriptions be developed; the climate-change context magnifies this reality. Understanding that a range of options exists, with some options appropriate to the short-term and others effective for the long-term, better positions decision-makers for the realities of changing times and dynamic landscapes. Below we suggest broad tools that currently occupy the toolbox—over time and with experience, the toolbox will grow and become filled with diverse and concrete examples, case studies, and lessons learned. Now and later, tools should be mixed and combined to best match the particular management context under consideration.

Contents of the ToolBox: Adaptation, Mitigation and the “5-R Strategies”

Adaptation and Mitigation. At the highest level in the toolbox are two broad climate-change strategies: *adaptation and mitigation* (IPCC 2007a). Adaptation implies all those approaches taken to adjust, prepare, and accommodate new conditions that are created by changing climates. Adaptations may be cultural and societal, for instances families deciding to purchase flood, fire, or windstorm insurance, or utility companies expanding energy capacities to accommodate unprecedented heat-wave surges. For managers, adaptation strategies include those actions taken to assist natural resources (species, habitats, forest plantations, watersheds) in accommodating the changes and new conditions imposed by climate. Mitigation strategies include those actions taken to reduce and reverse the human influence on the climate system, primarily through reduction of greenhouse gas emissions and feedbacks.

Adaptation and mitigation strategies are best considered joint paths—these primary tools optimally are combined and integrated. Thankfully, approaches to adaptation and mitigation will often be complementary: what is best management practice for one is also for the other. However, especially in forest- and ecosystem-management situations, conflicts are very likely to arise. Thus, evaluating pros and cons of short- and long-term choices becomes extremely important.

We outline five broad sub-strategies within the adaptation-mitigation toolbox. For didactic purposes, we call these the “5-R” strategies. They are summarized in order from most conservative to most pro-active; an informal “handle” is offered for each as a descriptive label.

Adaptation Strategies: 1. Increase **Resistance to Change.** “*Homeland Security*” approach. Defending high-value resources against change is an appropriate and defensible, if short-term, approach for resource managers under certain circumstances. High-risk, high-value, and/or extremely urgent situations, such as critically vulnerable endangered species, extreme fire-risk situations, or volatile invasive species epidemics, are most appropriate subjects for resistance management. In such cases, using great force to armor resource against change may be the best option. This action may be extremely expensive, take much time, resource, and staff effort, and be possible only for the short term. An example of resisting environmental change against great odds of success has been the program to captively propagate and reintroduce the California condor. Other examples include creating in-situ refugia for endangered species, constructing thorough fire

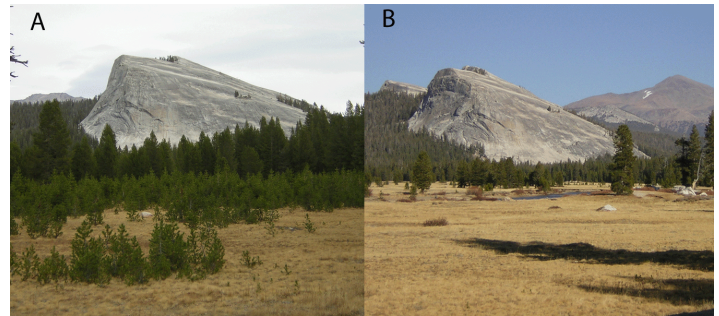


Figure 1. Managing for resistance to change. Invasion by lodgepole pine (*Pinus contorta*) is a common response to warming 20th-21st century conditions in Sierra Nevadan meadows. At Tuolumne Meadows, Yosemite National Park, CA, climate change and other historic land uses have interacted to promote recurrent colonization episodes of pine (A). National Park Service managers have chosen to resist and counter these effects by periodically removing pine seedlings and small trees (B). Photo: C. Millar.

breaks, conducting early-detection rapid-removal programs on new invasions of undesired exotic species, or erecting tarps over snowfields in alpine ski-areas (Fig. 1).

Resisting change is likely to be risky; in many situations conditions will eventually become so different that a resource threshold passes and resistance becomes futile. Then, an undesired consequence can be that the system ratchets forward catastrophically (burns, floods, falls into an extinction vortex). Thus, choosing to resist change might be considered a “paddling upstream” option.

Adaptation Strategies: 2. Promote **Resilience to Change.** “*Health Care*” approach. Promoting resilience is the most commonly discussed adaptation strategy (Dale et al. 2001, Spittlehouse and Stewart 2003). When a species, habitat, watershed or other natural resource returns to its former condition or function after disturbance, it is said to have resiled. In that climate change brings new types and intensities of extreme events, management actions to promote resilience are those that improve the capacity to return to desired prior conditions after climate-induced disturbance. The widely held assumption, adopted from human health-care philosophy but relatively untested in natural ecosystems, is that “healthy” species, forests, ecosystems are more resilient to change. Thus, preventative treatments aimed at increasing health, are prescribed. Depending on the situation, these might include thinning dense forests, prescribing fires, stocking seed banks, or augmenting endangered species’ populations (Fig. 2). In mountain ski-resort communities, an action to promote resilience to climate-change-induced low-snow winters might be to add snow-making equipment. As in resistance options, strategies to promote resilience are likely only successful in the relatively short-term,



Figure 2. Promoting resilience to change. Before- (top) and after- (bottom) thinning treatments to improve resilience to wildfire in pine forests at the Blacks Mountain Experimental Forest, northern Sierra Nevada, CA. The treatment included mechanical thinning plus prescribed fire; resilience was proven highly effective in the treated areas in the aftermath of the 2002 Cone Fire (Ritchie et al. 2007). Photo: John Ahnstead, USFS.

in that eventually changed climates will force new environmental conditions such that ecological re-setting rather than resilience will be “healthiest” path toward adaptation.

Adaptation Strategies: 3. Enable Ecosystems and Resources to Respond to Change. “Beginner’s Mind” approach. Responding to and managing change is the most proactive approach we describe. This strategy assumes that a decision-maker acknowledges the inevitability of change and adopts the humility that we have limited capacity to understand what change will happen at the scales needed by managers. Many types of actions can assist species, ecosystems, or resources to move to new and adapted conditions and processes. Some choices are highly deterministic—that is, acting as if we can predict what changes will occur. Others are based on uncertainty about direction of change. The following are examples of possible tools:

Assist species and resources to follow changing environments. Using ecological and climatic knowledge, augmented with information from available downscaled regional climate models,

directed decisions may be made about ecological restoration, reforestation, fire & flood reclamation, etc. For instance, species (seed, seedlings, capture/release individuals) could be moved from warmer (downhill, south aspect, or warm range margin) environments to cooler locations. Such an approach may entail moving propagules outside their current native ranges and into “neo-native” locations (Millar 1998). This assisted migration remains little tested and highly debated in the scientific and conservation literature (McLachlan et al. 2006). Establishing forest or restoration projects on what had been considered “off-site” locations is another example of assisting species to follow change, as is altering the composition of species in plantations from former associations to new mixes.

Anticipate and plan for associated risks. Already resource managers are experiencing the kinds of changes, especially in extreme events, that are catalyzed by climate change. These include, for instance, massive insect outbreaks and unprecedented forest diebacks, extreme fire events, fires and insect mortality in subalpine forests and other high-elevation environments, year-round fires, and extreme wind and flood events. Preparing for these, for



Figure 3. Enabling response to change. Seed transfer rules, based on zones such as those of the California federal, state, and private forest-genetic programs, have been developed to restrict movement of germplasm from source areas to restoration locations under the assumption that local genotypes are better adapted than non-local. Relaxing the guidelines and increasing diversity by mixing small percentages of seed from zones adjacent to the restoration sites may improve adaptation in the face of changing climates. Photo: California Dept. of Forestry and Fire Protection.

instance by retaining entomological expertise, year-round fire staff including fire ecologists, and Wilderness resource monitoring, are proactive choices.

Experiment creatively and learn from experiments. By spreading risks and employing “bet-hedging” practices, much can be learned about how species adapt to new environments. This might entail, for instance:

- Using redundancy. In forest plantation, post-fire reforestation, or ecological restoration, using redundancy in project locations may be useful, e.g., planting on several traditionally non-optimal sites for species (up, down, different aspects, species range margins).
- Relaxing genetic-management guidelines. Rather than adherence to strict on-site or near-site germplasm standards and transfer rules for propagule collection and replacement, a choice may be made instead to augment genetic diversity by collecting from adjacent seedzones or populations for restoration projects (Fig. 3).
- Experimenting with refugia. From a paleo-ecological perspective, some types of environments appear to have buffered species through climate change better than others, and served as local refugia during adverse conditions. Establishing such areas as refugia for some kinds of species might prove successful in maintaining their persistence so that they can serve as propagule sources for adapted new populations.

Increase diversity. A widely held assumption, from financial investing to forest health, is that diverse conditions withstand threat and unstable times better than homogeneous conditions. Diversity also favors adaptive responses by increasing the pool of candidates available for selection in new environments. Increasing diversity in ecological habitat, forest plantations, riparian ecosystems, watershed conditions, or rural community capacities (extending from ski-resort to four-season resort) may be a prudent strategy. Diverse landscape conditions break up opportunities for synchronous events, such as massive insect outbreaks (Mulholland et al. 2004) An opportune time to promote diversity is during post-disturbance management.

Promote connected landscapes. Over eons of natural climate change, species adapted primarily by migrating to new locations (range shifts). This is successful only when species have suitable habitat and adequate time to colonize new environments. Managers can assist this natural process by fostering connected landscapes (e.g., riparian zones), delineating large management-unit areas, lowering fragmentation, and increasing management flexibility.



Figure 4. Realigning ecosystems far out of the range of natural variability. Rather than using the common rule to target historic pre-disturbance conditions and lake level elevation as a restoration effort for Mono Lake's aquatic ecosystem, the 1990 court settlement and subsequent policies used water balance and climate models to develop goals that would re-align the lake level to current dynamics and anticipated future climates. Photo: C. Millar.

*Adaptation Strategies: 4. **Realign** Conditions to Current and Future Dynamics.* “Auto-Mechanic” approach. For systems that have been pushed (manipulated, disturbed) far out of range of current variability, actions that promote alignment with current conditions and processes may be the best approaches for restoration rather than returning to historic conditions. Using historic range of variability and returning habitats to pre-settlement or pre-disturbance conditions, which are widely used models for ecosystem restoration, will often be inappropriate because so much change has occurred since pre-disturbance times. In western North America, for instance, pre-settlement period is the mid-1800s, which coincides with the coldest part of the Little Ice Age. Clearly these are inappropriate conditions to use as a target for the 21st century environments. Re-aligning or tuning to current and anticipated environments and processes is more likely to be successful (Fig. 4).

*Mitigation Strategies: 5. **Reduce** Greenhouse Gases and Reduce Non-Renewable Energy Use.* “Good Samaritan” approach. The forestry sector in particular has an enormous opportunity to reduce human influences on the climate system. Reducing greenhouse gases can be achieved through forest and wildland management actions designed so that sequestration is enhanced, carbon stored in natural resources (wood, fiber, soil) is retained longer, emissions are lowered (by reducing severe fire), and non-fossil fuel alternative energy favored (e.g., biomass utilization)

(Fig. 5). By contrast, poor management, lack of management, or inadequate capacity to manage can inadvertently accelerate negative effects, for instance through increase of large, catastrophic forest fires.

All resource sectors have abundant opportunities for reducing energy consumption and reducing the human energy footprint. Increasingly these options are available in all aspects of our work and personal lives. Carbon markets and law and policy (e.g., California AB-32, the California Global-Warming Solutions Act) promote actions designed to reduce human influence on climate.

Setting Priorities

Climate-change pushes the resource-manager's already full plate to overflow. More than ever, demands will exceed capacity and conflicts among choices will have higher stakes. Evaluation of options and setting priorities will be increasingly important. At an overall level, decision-makers have three options for engaging climate-management, each defensible under different scenarios. They can do nothing (no advance planning), react after disturbance or extreme events (when trajectories are often adaptively reset under natural conditions), or act proactively in advance (Joyce et al., in press).

Priority-setting is a science in itself; several approaches to priority setting have been discussed in the climate-context. These include tiered approaches such as no-regrets, low regrets, win-

win (Willows and Connell 2003), and employing low- to high-technology approaches judiciously (Ralph 2007). Formal triage approaches, developed and used widely in military and emergency medicine, can be successfully adopted in resource situations whenever time is short and capacity to meet urgent demands inadequate. Systematically evaluating vulnerabilities provides an essential first step in all approaches (IPCC 2007b).

Summary

We describe a preliminary and overarching framework appropriate to western mountainous environments for developing forest and natural-resource management strategies in the face of climate change. Adaptation and mitigation approaches may be divided into short- and long-term options following the "5-R strategies": Increase resistance, promote resilience, enable response, encourage re-alignment, and implement practices to reduce the human influence on climate. Priority-setting, especially embracing methods that empower decision-making under urgent contexts where demand is greater than capacity to respond, becomes very important. While general principles will emerge, the best preparation is for managers and planners to stay closely turned to local environments and resources, remain informed about relevant emerging climate science in their regions, and to use that knowledge to shape effective local solutions. A goal of this article is to engage dialogue on this issue.

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Figure 5. Reducing greenhouse gas emissions. Biomass production from wood fiber removed during forest fuel reduction treatments provides alternative energy, thereby reducing fossil-fuel dependent energy consumption and ultimately lowering greenhouse gas emissions. Photo: Mark Nechodom, USFS.

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Monitoring the Pulse of Our Planet—The USA-National Phenology Network (USA-NPN)

Phenology at High Elevations in the Western US

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Now that the scientists of the Intergovernmental Panel on Climate Change have concluded that the warming of our globe is “unequivocal,” many have asked the question, “How are organisms and natural processes responding?” The import of the answer goes beyond mere curiosity; it is key to developing informed adaptation strategies. A new US national network has been initiated to include scientists, citizens and government agencies to coordinate efforts to track the response of plant and animal phenology to ongoing and future climate changes.

Phenology, which is derived from the Greek word *phaino* meaning to show or appear, is the study of periodic plant and animal life cycle events, which are influenced by environmental changes, especially temperature variations driven by weather and climate. Wide ranges of phenomena are included, from first openings of leaf and flower buds, to insect hatchings and bird migration. Each pheno-phase gives a ready and integrated measure of the environment as experienced by the associated organism. Moreover, synchronicity of pheno-phases, or lack thereof, impacts future ecosystem structure and function in non-linear ways. For example, a mismatch of flowering with the presence of its pollinator could easily begin a cascade effect completely reorganizing the present ecosystem.

The passing of the seasons, recorded in the phenology of organisms, is the most pervasive source of biological variability available on Earth. It is possible to link, or scale, changes observed in phenology from cell division to individual organisms to landscapes to satellite imagery, meaning the pulse of entire regions can be tracked through observations beginning with individual organisms. For example ground-based observations of tree growth onset, such as leaf-out, are related to ecosystem carbon sequestration, energy and hydrological fluxes. In turn, these parameters can be linked to the spectral signature of the forest canopy as detected by digital cameras or air or space borne spectral imagery. Calibration of phenology observations across scales in this manner enables ready assessment of the impact of local- to global-scale changes in weather and climate on the Earth's biosphere.

Phenology constitutes a critical component of the biosphere and the climate system at all scales. The phenological attributes of an ecosystem or habitat also reflect its biodiversity and structure, as well as its ability to regulate biogeochemical cycles and to sustain life (Figure 1). Scaling from the individual to higher levels of organization enables logistically simple and inexpensive methods to monitor phenology at these levels, and measurements across elevational gradients maximizes the return on research programs and individual observations. Phenological events also indicate, in a real and immediate manner, the consequences of environmental variability and change vital to the public interest. Further, phenology has important socio-economic applications including human health, resource management, education, gardening, recreation, transportation, agriculture and forestry (Table 1).

Phenology in the USA has traditionally been tied to agricultural applications and the illustration of extreme climatic effects at the local scale. However, over the last decade there has been a growing awareness of its potential to increase understanding of Earth systems interactions in many areas. These include: 1) at-

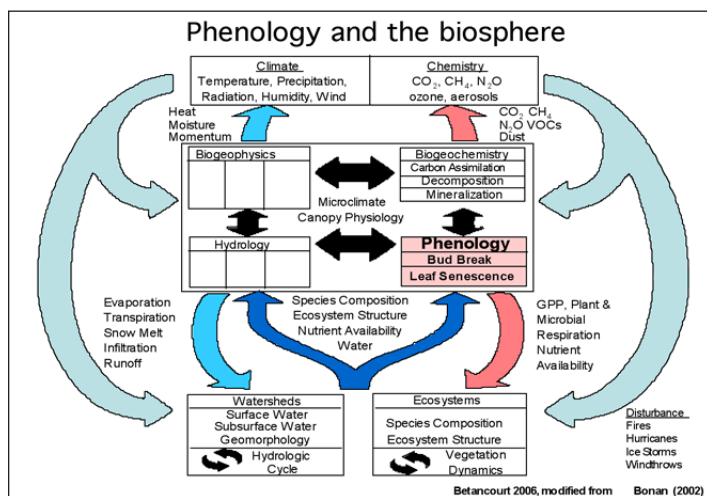


Figure 1. Phenology is an essential component of environmental science. Phenological phenomena interact with biospheric processes at scales from local to global, from minutes to centuries (Adapted from Bonan, G.B. 2002, Ecological Climatology, Cambridge University Press).

<u>Scientific Research</u> Effects of climate variability & change, ecological forecast models, ecological synchrony, carbon sequestration, ground truthing for remote sensing, ecohydrology	<u>Human Health</u> Timing and prediction of allergy (hay fever) and pulmonary (asthma) problems. Study of vector-borne diseases (lyme disease, avian influenza, West Nile virus)
<u>Agriculture</u> Timing of management activities (pest and disease control, planting, harvesting, and provision of pollinators), drought monitoring, range management	<u>Natural Resources</u> Prediction of forest pest and disease outbreaks, fire management, invasive species management, watershed management, selection of species and varieties to be used in 'assisted migration' to conserve ecosystem services as climate changes
<u>Tourism and Recreation</u> Informing tourists when and where to go for seeing bird migrations, wildflower displays, and fall colors	<u>Education</u> School children and citizen scientist involvement in scientific observations; establish college curriculum in phenology that encourages local observations and educational use of the data products of the network

Table 1. Examples of six areas to which phenological research can contribute.

mosphere-biosphere interactions; 2) long-term organism response to climate change; 3) phenology databases for monitoring and management at the regional, continental, and global scales; and 4) predictive models to inform strategies for human adaptation to ongoing and future climate change. Thus, broad-scale phenology data are needed, and while phenology networks have been in place in Europe, Canada, Australia, and China for some time, in the USA only phenology of lilacs (*Syringa*) has been recorded at near-continental scales, and collection of these data has been especially sparse since the early 1990s.

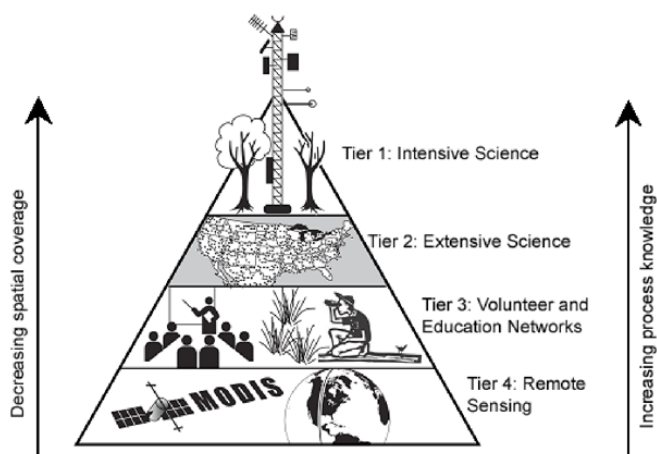
To fully utilize the predictive potential of phenology, however, scientists require a new data resource—a national network of integrated phenological observations and the tools to access and analyze them at multiple scales. The USA-National Phenology Network (www.usanpn.org) is a new enterprise—a wall-to-wall science and monitoring initiative focused on phenology, intent on the realization of phenological potential through the development of integrated data sets that include phenological observations of individual plants and animals as well as entire landscapes and regions using remote sensing platforms from the air and from space (Figure 2).

The National Coordinating Office (NCO) of the USA-NPN recently opened its doors to meet this exhilarating challenge. The function of the NCO is to facilitate and coordinate data collection at all scales, acting as a coordination center and sharing successful strategies among those working on similar issues and projects. In anticipation of an active NCO, there has been wide participation in planning and implementation of USA-NPN from individuals at over twenty universities and many federal agencies, primarily the US Geological Survey (USGS), the National Science Foundation (NSF), and US Fish & Wildlife Service (USF-

WS), as well as the National Park Service (NPS), Bureau of Land Management (BLM), US Department of Agriculture (USDA) Forest Service and Agricultural Research Service, National Aeronautics and Space Administration (NASA), National Oceanic and Atmospheric Administration (NOAA) and the Environmental Protection Agency (EPA).

The USA-NPN can benefit from and contribute to many existing local, state, federal and non-governmental organizations that are concerned about nature and climate. Close collaboration with these organizations represents not only the best use of available resources but also the best scientific practice. The USA-NPN Collaboration Plan seeks to (1) coordinate research activities with existing networks to advance phenological science and develop mechanistic phenological models to support improvement of climate and ecosystem models; (2) maximize the representation of phenological monitoring sites at the national and regional scale to enable biological baseline characterization and trend detection; and (3) provide data and information to policy makers to support land management decisions related to agriculture, forestry, and wildlife conservation in regard to the mitigation of climate change impacts. Collaboration principles include mutually beneficial activities, shared vision on science/education/outreach, minimizing the demand on the capacities of partners, feedback to improve collaboration, and transparent data and information sharing policies.

A strong component of the USA-NPN is education and outreach, realized in part through education and citizen science programs. These programs will allow the public and scientific professionals throughout the US to work independently and together to observe and interpret phenological patterns on an unprecedented scale. Each program is designed to achieve one



Adapted from the Committee on Environmental and Natural Resources Research, U.S. Office of

Figure 2. The USA-NPN conceptual diagram. The USA-National Phenology Network is a large-scale network of repeated and integrated phenological observations, linked with other relevant data sources and the tools to analyze these data at local to national scales. It will integrate with other observation networks, including regional phenology networks, remote sensing products, emerging technologies and data management capabilities, and will capitalize on myriad educational opportunities and a new readiness of the public to participate in investigations of nature on a national scale.

or more of the following objectives: (1) engage the public in long-term phenological data collection and analysis through both formal and informal science education programs; (2) engender self-directed, voluntary learning using inquiry-based approaches; (3) engage currently active land stewards, networks, and master naturalist programs in the collection and contribution of phenological data; (4) provide training in the tools and applications of phenological studies to citizens and to scientists at all stages in their careers; (5) enhance opportunities for the public to interact with professional scientists; and (6) promote novel tool development and collaboration among scientists representing historically distinct disciplines. As one example, Project BudBurst, www.budburst.org, last year successfully invited public observers to validate protocols for leafing and flowering of 54 plant species with the intent of tracking spring onset, and is preparing for an even larger and more successful 2008 season.

NCO activities are focused on the development and implementation of a beta version of a national plant phenology program for the 2008 growing season. This project entailed development and vetting of a core suite of plant species representative of large regions within the nation, determination of critical phenophases for monitoring for each plant species, and development of study design protocols. The NCO is also actively

scoping and developing a national animal phenology program for possible implementation as soon as 2009. Other activities include the coordination of remote sensing of phenology, development of collaborative agreements with other science and education networks and individuals, and fostering development of regional phenology networks (e.g., the Northeastern Regional Phenology Network, NE-RPN).

Regional phenology networks are crucial to capturing phenological developments at the regional scale, and enable a focus on regionally important species and processes (e.g., leaf color change in deciduous trees typical of northeastern US forests). Attention at the regional level captures issues crucial to ecosystem function at this scale, and may also serve as early indicators of developing national trends. For example, a strong phenology data base in the western US may aid the management of invasive species, help predict the potential for forest fires, and can be used to improve predictions of snow-melt, run-off and water production. Airborne dust events impact the rate and timing of snow pack melting, which in turn has broad direct and indirect impacts on water supply quantity and quality; forest fire seasonality, frequency, and intensity; and human health. Dust source characteristics including season timing, duration, and areal extent, are directly linked to small plant phenology on seasonal time scales, and larger species on longer time steps. Finally, process-based ecosystem models such as PHENOFIT, BIOMOD, and CASTANEA can use phenology data to predict species abundance and distribution under changing climates, and can help identify future sites of species survival, information important now for land managers and natural resource planners.

There are obvious opportunities for collaboration between CIRMOUNT and USA-NPN given our common goal of better monitoring and understanding of patterns and trends in climates of the western US, as well as predicting effects of climatic variation on ecosystem structure and function. The USA-NPN recognizes the tremendous advantage of elevational gradient studies to maximize research returns. Compressed elevational zones provide a logistically expedient venue to monitor a wide range of climatic regimes at humanly measurable scales, largely free of local anthropogenic disturbance, thus representative of the free-tropospheric (i.e., global) environment, and in many ways are more sensitive to climate. Therefore, a CIRMOUNT focus capitalizing on these premier opportunities for phenological studies in concert with climate monitoring, portends particularly rich environmental research returns.

The NPN can help CIRMOUNT meet their goals by providing

nationally vetted species lists and monitoring protocols to all CIRMOUNT participating sites, and coordinating phenology observations environmental networks. Collaborative networks currently include the NOAA Climate Reference Network, the Long Term Ecological Research network, Ameriflux, the National Ecological Observatory Network, and the nascent Arizona Environmental Array (ARENA) Coupling phenology with related environmental data, such as that of CIRMOUNT's MoNet instrumented climate network, provides the basis for identification of the climatic drivers of phenophase change, important to developing adaptation strategies for the future. The coordinating role is key to the NPN vision, and CIRMOUNT collaboration would be an effective venue to realize our common goals.

Thus, a focus on phenology enhances our ability to understand and respond to the effects of global climate change, and cannot be overestimated. Baseline phenological data is needed to understand current conditions and parameterize models, as well as distinguish natural variations in climate or biological responses from potentially serious tipping points that may lead to irreversible ecological changes, and finally to our ability to develop appropriate strategies for coping with such changes when and if they occur. Explicitly adding phenology observations at CIRMOUNT sites is a powerful step toward tracking these changes, identifying drivers of phenological changes, and better informing adaptation strategies for a climatically changed future. The USA-NPN looks forward to a long, and prosperous association with CIRMOUNT, MTNCLIM, and MONET.

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THE USA-NATIONAL PHENOLOGY NETWORK

The USA National Phenology Network (USA-NPN) is an emerging and exciting partnership between federal agencies, the academic community, and the general public to monitor and understand the influence of seasonal cycles on the Nation's resources. The goal of the USA-NPN is to establish a wall-to-wall science and monitoring initiative focused on phenology, the seasonal pulse of the biosphere and thus the gateway to climatic effects on ecosystems and ecosystem services.

The National Coordinating Office (NCO) of the USA-NPN is housed on the University of Arizona campus, in the Office of Arid Lands Studies building at 1955 E. Sixth Street, Tucson, AZ 85721. Jake Weltzin, Executive Director, and Mark Losleben, Assistant Director, form the core of this new office, with plans to grow its staff with plant and animal phenology, information management systems, and remote sensing phenology personnel in the near future; two additional half-time staff are already on-board.

REGIONAL PHENOLOGY NETWORKS

The NCO of the USA-NPN actively promotes regional phenology network development. Currently there is a strong regional phenology network in the Northeast (NE-RPN), a proposal submitted for a Southeast network, discussions for a Mid-Atlantic network proposal, and a nascent southwestern phenology network taking root in collaboration with the SW chapter of ASPRS and the Arizona Environmental Array (ARENA) network. We look forward to germinating more regional phenology networks, particularly in the western US where the benefits and needs are arguably disproportionately greater than either its population or space suggest. The NCO of the NPN will actively work with individuals or groups to develop regional networks.

Adapting to Climate Change on Olympic National Forest

Dave Peterson, U.S. Forest Service, Seattle, WA
 Jeremy Littell, University of Washington Climate Impacts Group, Seattle, WA
 Kathy O'Halloran, Olympic National Forest, Olympia, WA

A research-management partnership is working to develop management options for adapting to climate change on Olympic National Forest (ONF) in northwest Washington state—the first step in moving towards implementation of climate change in large-scale management and planning. This effort has changed the context for management on ONF, raised awareness of the effects of a major extrinsic factor on resource objectives, and generated enthusiasm on national forests in the Pacific Northwest regarding adaptation to climate change.

ONF is located astride the Olympic Mountains in the northwest corner of Washington. Ranging from sea level to alpine wilderness and with annual precipitation ranging from 50 to 500 cm, the Olympic Peninsula supports a high diversity of vegetation and wildlife including many endemic species. ONF is considered a “restoration forest” with the primary goal of managing second-growth forests toward structure that will support late-successional habitat. Formerly a supplier of wood to regional and global timber economies, ONF now focuses on the resource values of biodiversity, water, and recreation.

Natural resource managers on the ONF are among the first national forest managers in the West to actively explore the potential effects of climate change on their lands and to express interest in developing adaptation options. As a first step, ONF staff organized a “climate change science day” at the forest with presentations on climatology and the effects of climate change on a wide range of resources. Although primarily an educational experience, it was also an opportunity for staff to begin to articulate how climate change might affect different resource areas.

As a second step, scientists from the US Forest Service Pacific Northwest Research Station and the University of Washington Climate Impacts Group convened a one-day focus group to identify management options for adapting to climate change. The following questions were posed by scientists to elicit information from ONF managers:

- What are priorities for long-term resource management (>50 years)? How can climate change be integrated in planning at this time scale?
- What is the policy and regulatory environment in which management and planning are currently done?
- What are the biggest concerns and ecological/social sensi-



Increased flooding would affect water quality, fisheries, and recreation. It would also require road and drainage infrastructures that can handle increased flows.

tivities in a changing climate?

- Which management strategies can be used to adapt to potentially rapid change in climate and resource conditions?
- Which information and tools are needed to adequately address the questions above?
- Which aspects of the policy and regulatory environment facilitate or hinder management that adapts to climate change?

The engaging discussion that ensued demonstrated that ONF managers were remarkably adept at articulating promising adaptation options in the context of local resource and regulatory contexts. It must be emphasized that these options were developed by managers with experience on the land, with scientists in the focus group acting primarily as facilitators.

ONF managers described three general adaptation guidelines:

Reduce Vulnerability

The success of adaptation strategies should be defined by their ability to reduce the vulnerability of resources to a changing climate while attaining specific management goals for the condition of resources and production of ecosystem services. For structures, using designs and engineering standards that match future conditions (e.g., culvert size) will help minimize future crises.



Pacific salmon are sensitive to increased water temperature and to increased sedimentation from erosion and flooding.

Consider Tradeoffs and Conflicts

Future impacts on ecological and socioeconomic sensitivities can result in potential tradeoffs and conflicts with respect to species conservation and other resource values. For example, stress complexes exacerbated by climate change may cause rare species (e.g., bull trout, spotted owl, marbled murrelet, Olympic marmot) to become even rarer, thus undermining the likelihood of successful protection.

Prioritize Climate-Smart Treatments

Prioritizing treatments with the greatest likelihood of being effective in the long run recognizes that some treatments may cause short-term detrimental effects but have long-term benefits. For example, fish species may be vulnerable to failures of unmaintained roads caused by increased precipitation and storminess, but road rehabilitation may produce temporary sedimentation and may invite invasive weeds. Ideally, triage situations could be avoided, but given limited financial resources, it may be necessary to prioritize management actions with the highest likelihood of success at the expense of those that divert resources and have less certain outcomes.

ONF managers described seven categories of specific adaptation strategies:

Increase Landscape Diversity

- Apply targeted forest thinning to increase variability in stand structure, increase resilience to stress by increasing tree vigor, and reduce vulnerability to disturbance.
- Implement a variety of thinning and harvest treatments ap-

propriate for different landscapes and avoid “one size fits all” management prescriptions.

- Create forest gaps large enough for elk habitat but small enough to minimize invasive species.
- Design “no touch” preserves at many elevations, not just in high elevation wilderness.
- Maintain corridors that link habitat for animal species that migrate and have large home ranges.

Maintain Biological Diversity

- Plant appropriate species and genotypes in anticipation of a warmer climate, assuming credible scientific justification is available on which to base planting decisions. This allows resource managers to “hedge their bets” by diversifying the phenotypic and genotypic template on which climate and competition interact, and to avoid widespread mortality at the regeneration stage.
- Plant multiple tree species rather than monocultures. This would include common local species and perhaps species that are common in adjacent warmer landscapes.
- Plant nursery stock from warmer, drier locations than what is prescribed in genetic guidelines based on current seed zones. Plant nursery stock from a variety of geographical locations.

Implement Early Detection/Rapid Response for Invasive Species

A focus on treating small problems before they become large, intractable problems recognizes the importance of proactive management. For example, the ONF land management plan recognizes that invasive plant species that establish in small patches can sometimes be eradicated. Although designed for situations like invasive plants, early detection/rapid response is also appropriate for climate change because it can allow managers to respond quickly to extreme events (disturbances, floods, windstorms) with an eye towards adaptation.

Treat large-scale disturbance as a management opportunity. Large-scale disturbances can cause large changes in ecosystems, but are also opportunities to apply adaptation strategies. ONF is currently climatically buffered from chronic disturbance complexes already evident in drier forests, but age-class studies and paleoproxy evidence indicate large-scale disturbances occurred in the past. In British Columbia to the north, harvest practices played a role in the current mountain pine beetle outbreak by homogenizing forest structure over large areas. In ONF, the amount of young forest (as a result of 20th century harvest) is both a risk

(hence the ONF emphasis on restoration) and an opportunity. Large disturbances can be used to influence the future structure and function of forests through planting and silviculture. Carefully designed management experiments for adapting to climatic change can be implemented, provided that plans are in place in anticipation of large wind and fire events.

Match Engineering Of Infrastructure to Expected Future Conditions

- Decommission roads that have low use and are difficult to maintain, and restore vegetation where necessary.
- Design and maintain roads to accommodate increased winter runoff.
- Install culverts that can handle increased peak flows of water and debris movement in winter. Maintain drainage systems that limit increased sediment delivery to streams during winter peak flows.

Promote Education and Awareness About Climate Change

- Conduct trainings at ONF to ensure that employees understand climate change science and that scientists understand the climate information needs of employees.
- Develop interpretive programs and materials that help educate ONF visitors and stakeholders.
- Develop educational materials that document the role of active management in adaptation.
- Work with the scientific community to ensure awareness of recent scientific discoveries

Collaborate With A Variety Of Partners On Adaptation Strategies

- Work closely with Olympic National Park to ensure compatibility of management objectives and adaptation strategies.
- Work with a diversity of local landowners, agencies, and stakeholders, including those perceived to be antagonistic, to develop support for adaptation strategies.

These adaptation options comprise a set of management approaches that ONF managers think would be reasonable and appropriate for creating resilience to a warmer climate while still attaining desired resource outcomes. Implementation of many of these options would be challenging, given the constraints of regulations (e.g., US Endangered Species Act), policy (e.g., Northwest Forest Plan), and process (e.g., National Environmental Policy Act), all of which would prohibit or delay active management. It is interesting to note that an independent research-management



Roosevelt elk, whose habitat may be affected by future vegetation changes, need to be managed across large landscapes and multiple ownerships.

focus group on the Tahoe National Forest (California; led by Connie Millar, US Forest Service, Albany, CA), using the same questions, developed a list of adaptation options that overlapped considerably with those developed by ONF. Although these are only two examples, they suggest that some adaptation approaches may be broadly applicable across national forests in the West.

Developing a list of adaptation options is only the first step in incorporating climate change in management at ONF. The second step is to compile the necessary scientific documentation needed to support decision-making and large-scale management experiments. The final step is to implement climate change in the planning processes used to implement strategic and operational management. Planning and public review are often frustratingly slow, yet this is where changes must be approved prior to implementation.

ONF resource managers realize that there is some urgency to changing the direction of management. Storms and flooding during the winter of 2006-07 caused \$70 million damage to infrastructure on public lands in western Washington. Cyclonic storms this past winter flattened over 40,000 ha of forests in western Washington. While these events are probably related to climatic variability rather than climate change, they exemplify the kinds of large disturbances that could occur more frequently in the coming decades. Timely planning and action will improve the likelihood of successful adaptation to these kinds of disturbance events.

Taking the Pulse of Mountain Forests: The Cordillera Forest Dynamics Network (CORFOR)

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The Need for a Cordillera Forest Dynamics Network

Forests provide us with irreplaceable goods and services such as wood, clean water, biodiversity conservation, and recreation. Additionally, forests sequester the majority of the terrestrial biosphere's carbon, making them potentially key contributors of feedbacks to global climatic change. These vital forest functions add a sense of urgency to recent observations that at regional and global scales, rapid environmental changes may be altering the structure, composition, and dynamics of forests (Lewis et al. 2004, Lapenis et al. 2005, Boisvenue & Running 2006). For example, over the last several decades average global forest productivity apparently has increased, perhaps due to various combinations of increasing temperature, precipitation, cloudless days, atmospheric CO₂, and nutrient deposition (Boisvenue & Running 2006). However, there are notable regional exceptions to this trend, particularly in water-limited forests experiencing ongoing climatic warming without compensating precipitation increases. For example, growth of European beech (*Fagus sylvatica*) has declined at its southern range limit in Spain (Jump et al. 2006), tree mortality rates have increased in California's Sierra Nevada (van Mantgem & Stephenson 2007), and arid forests of the southwestern U.S. have experienced sudden, extensive die-back (Breshears et al. 2005). Such observations underscore a need to improve our ability to understand and predict climatically-driven changes in forests.

The effects of ongoing global changes on tropical rain forests remain controversial. On one side, some researchers have suggested that tropical forests are currently increasing in biomass, and so functioning as a carbon sink (Phillips et al. 2004, Lewis et al. 2004). On the other side, some studies have shown exactly the opposite, with decelerating growth rates in tropical forests possibly due to increasing temperatures (Wright 2005, Feeley et al. 2007). Although the latter authors identified a negative correlation between growth and annual mean daily minimum temperatures, the underlying causes of the growth deceleration remain unresolved (Kenneth et al. 2007). However, these contrasting results come from lowland tropical forests, and very

little is known about trends in montane tropical forests. The possibility remains that montane tropical forests might behave more like moist temperate forests than like lowland tropical forests. For example, increasing temperatures might enhance growth in montane tropical forests. Indeed, one of the main expected effects of global warming is the upward expansion of the current tree line of montane forests.

The task of improving our understanding of forest changes is made difficult by the great spatial and temporal scales encompassed by forest dynamics, which preclude most forms of experimentation. For this reason, researchers have relied heavily upon forest models to forecast possible effects of climatic changes on forests. But these models often rely on untested assumptions, and most models were never designed to forecast the consequences of large, directional climatic changes (e.g., Loehle & LeBlanc 1996, Bugmann 2001, Keane et al. 2001). Thus, our ability to forecast climatically-driven changes in forests remains remarkably rudimentary. Clearly, we must find other ways to improve our mechanistic understanding of climatic effects on forests.

Fortunately, our understanding can be greatly improved by taking advantage of "natural experiments" in space and time. Natural experiments in space take advantage of regional to global environmental gradients to help elucidate environmental controls of forest structure, biodiversity, and dynamics. For example, mortality and recruitment rates of trees increase both with decreasing elevation in California's Sierra Nevada and with decreasing absolute latitude at global scales, suggesting that forest dynamism increases with increasing potential for forest productivity (Stephenson & van Mantgem 2005). Natural experiments in time take advantage of changing environmental conditions to help elucidate mechanisms driving forest changes. For example, increasing tree mortality rates in California's Sierra Nevada appear to be the result of a temperature-driven increase in drought (van Mantgem & Stephenson 2007).

The tremendous value of international networks of forest plots has been well demonstrated by the Center for Tropical Forest Science (CTFS; <http://www.ctfs.si.edu/>) and the RAIN-

FOR network (<http://www.geog.leeds.ac.uk/projects/rainfor/>). However, both of these important networks are mostly limited to lowland tropical forests, and therefore span rather limited environmental gradients.

In contrast, the American Cordillera offers unmatched natural experiments in space, in the form of numerous nested environmental gradients. Forests can be found at nearly any point along the Cordillera, from 65° N to 55° S, accompanied by an extraordinary range of climatic types (from tropical through temperate to boreal). Additionally, at nearly any point along the Cordillera, forests grow along steep elevational (temperature) gradients spanning thousands of meters, often overlain by west-to-east precipitation gradients crossing the Cordillera. At any given latitude and elevation, topographic and soils gradients add local environmental gradients for study.

CORFOR and its Goals

For these and related reasons, as a working group of the larger America Cordillera Transect of scientific research (<http://mri.scnatweb.ch/content/category/3/45/67/>) we have established the Cordillera Forest Dynamics Network (<http://www.corfor.com/>). This international group of collaborators maintains hundreds of long-term forest monitoring plots (including hundreds of thousands of trees) along the American Cordillera. No other forest network spans such a wide range of environmental gradients, and therefore offers comparable opportunities to understand the effects of environment on forests.

CORFOR's two primary goals can be summarized as follows. First, we wish to provide a means, complementary to remote sensing, for detecting and characterizing changes in forest structure, composition, diversity, and dynamics along the American Cordillera. Second, we wish to provide an improved mechanistic understanding of forest responses to environmental changes (particularly climatic changes), thereby improving our ability to forecast changes.

To reach these ends, forest plots must have several characteristics. For example, the recruitment, growth, and death of individually-identified trees must be tracked in repeated censuses, preferable at five-year intervals or less. The rationale for plot-based monitoring of individually-identified trees is simple. First, the approach gives precise measures of forest composition and structure for change detection. Second, and perhaps more important, it is the only approach that can hope to yield the information needed to develop models capable of forecasting or predicting future changes. Specifically, plot-based monitoring of individ-

ually-identified trees yields species-specific demographic rates and growth rates, and sheds light on their controls. Demographic rates determine numbers of trees, while growth rates determine sizes of trees. Together, species-specific numbers and sizes of trees precisely define forest composition and structure. Therefore prediction requires mechanistic understanding of environmental controls of species-specific demographic rates and growth rates.

Experience has proven other ground-based approaches to be less useful. For example, if trees are not individually identified, plot-based approaches effectively become repeated inventories rather than monitoring. Changes in forest structure and composition can still be detected, but ability to determine demographic rates and growth rates (hence ability to develop mechanistic models) is lost. Additionally, as empirical data from tropical forests have demonstrated, substantial parallel changes in mortality and recruitment (hence carbon cycling and other aspects of forest function) can occur with little change in forest structure and composition.

Future Directions

CORFOR has several objectives for the near future. First, we wish to grow as an open, collaborative network of forest scientists who share common interests. As such, we aim to learn from our collective knowledge and experiences, establish a common set of recommended protocols for forest plot establishment and monitoring, and establish common data formats to facilitate cross-site comparisons. Most important, we wish to establish the value of our network through one or more peer-reviewed publications exploring effects of environmental gradients on forest dynamics along the American Cordillera. Toward this end, we are convening a small workshop on 13 June 2008 in Silverton, Colorado, USA, immediately following the MTNCLIM 2008 conference (<http://www.fs.fed.us/psw/mtnclim/>).

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Forest Disease Conditions and Climate: What's Changed?

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Forest pathogens are widely cited as key disturbance agents under a changing climate (McNulty and Aber 2001; Dale and others 2001; Logan and others 2003) but are often glossed-over with generalizations. The principal theme emerging from a review of climate change and forest pathogens in Western North America is that the host-pathogen climate interactions are complicated and very uncertain (Kliejunas and others In Prep). While such general conclusions are true, they are not very helpful in deciphering how forest disease conditions may evolve due to climate change. Changes in temperature, precipitation and other environmental factors significantly affect all biotic forest pathogens, host tree physiology and their interactions (Ayers and Lombardero 2000). So, given climate change, what differences in forest diseases can land managers expect? In areas experiencing climate changes, how have forest disease conditions already changed? In this short article, five current forest disease situations are presented to represent conditions that might become more common given warming and related climate changes.

Changes in precipitation patterns, extreme weather, changes in snowpack, warmer winters, and drought offer current examples of changes in climate that have resulted in changes in forest disease conditions.

Changes in Summer Precipitation: Red Band Needle Blight/*Dothistroma Septosporum*

Red band needle blight is causing unprecedented mortality in northwest British Columbia, on over 40,000 ha of lodgepole pine (*Pinus contorta* var. *latifolia*) plantations and mature stands. The disease outbreak is associated with increases in summer precipitation that are beyond the range of previously recorded weather patterns (Woods and others 2005). The disease outbreak is particularly distressing since it is occurring adjacent to areas devastated by mountain pine beetle; the additional rainfall appears to have thwarted the mountain pine beetle but favored the pathogen. Red band needle blight is known as a severely damaging pathogen on planted *Pinus radiata* stands in the southern hemisphere where it is non-native, but this outbreak in British Columbia where the pathogen is considered native, is a new phenomenon. Red band needle blight in a lodgepole pine plantation in BC.



Red band needle blight in a lodgepole pine plantation in BC. Credit: A. Woods

Climate Extremes: Sudden Oak Death/*Phytophthora Ramorum*

Sudden Oak Death of tanoak (*Lithocarpus densiflorus*) in coastal California, as reflected in its name, appears in bursts—wave years with cohorts of trees appearing to succumb abruptly. The tree mortality pattern is driven by extreme weather events. Heavy rains during warm periods start the cycle by creating optimal conditions for inoculum production and infection. Infected trees suffer a reduced capacity to manage water but survive until high temperatures and extended dry periods overwhelm the



Sudden oak death of tanoak in Marin Co. CA. Credit: USDA-FS, SPF, FHP

trees' impaired vascular capability and large numbers die (Parke and others 2007). Two cycles of this pattern have been noted in California, 1998-2001 and 2005-2008 (Frankel 2007). (For more information on sudden oak death, see www.suddenoakdeath.org.)

Reduced Snowpack: Alaska Yellow-Cedar Decline

Yellow-cedar (*Chamaecyparis nootkatensis*) mortality has been on-going for decades on more than 200,000 ha, of lower elevations forests in southeastern Alaska. The mortality often occurs in expanding centers, a typical pattern for root diseases or other biotic forest diseases. The Alaska-yellow-cedar decline mystery was solved by noticing that areas with abundant dead yellow-cedar experienced temperatures that were relatively higher in the spring and summer, and lower in the winter, with reduced snowpack. After years of investigation, Paul Hennon and colleagues (2007, 1997) demonstrated that the mortality is related to earlier snow melt, which exposes yellow cedar's shallow, fine roots to colder temperatures, resulting in freeze injury. The root damage leads to tree death.

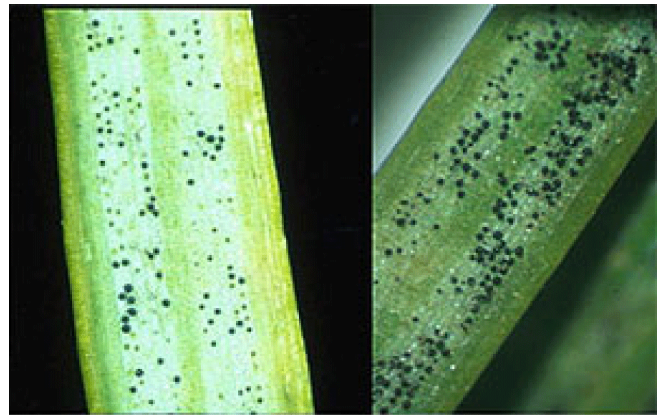


Alaska yellow-cedar decline. Credit: P. Hennon, USDA-FS, PNW

Warmer Winters: Swiss Needle Cast Damage (*Phaeocryptopus Gaeumannii*)

Since the early 1990s, Swiss needle cast, caused by *Phaeocryptopus gaeumannii*, has been increasing in Douglas-fir plantations, damaging 120,000 ha in the Oregon Coast Range. The pathogen reduces tree growth and kills trees. There is considerable variation in disease severity across the affected area. Contrary to expectations, disease severity was negatively correlated with shade and mist and positively correlated with warmer winter mean daily temperatures (Manter and others 2005). So, if warmer winters develop along the Oregon Coast, increased Swiss needle

cast damage is expected. (More information on Swiss needle cast may be found at the Swiss Needle Cast Cooperative website <http://www.cof.orst.edu/coops/sncc/>.)



Swiss needlecast on Douglas-fir needles. Credit: J.Stone, Oregon State Univ.

Drought-Related Pinyon Pine (*Pinus Edulis*) Mortality in the Southwest and Conifer Mortality in Southern California.

Drought, the direct impact of heat and the lack of soil moisture, combined with multiple stresses, with and without bark beetles and pathogens interactions, is causing widespread mortality in many areas. A dramatic example is the recent drought in Arizona and New Mexico causing decline of pinyon pine (*Pinus edulis*) across 12,000 km² of the Southwest (Breshears and others 2005). In Southern California, the worst drought in the recorded history of the region, in combination with stress induced by overstocking, dwarf mistletoe, and root disease predisposed conifers to bark beetle attack. The tree mortality provided fuels for fall 2003 wildfires that caused over \$2.5 billion in damage (Keeley and others 2004, Kliejunas and others In Prep).

In short, changes in precipitation patterns, extreme weather, changes in snowpack, warmer winters, and drought are currently influencing forest disease conditions in Western North America. A literature review of climate and forest pathogens in the West is now available at http://www.fs.fed.us/psw/topics/climate_change/forest_disease/. An annotated bibliography is under development. We are expanding these notes on changes in forest health conditions due to climate to include forest insects and climate interactions and hope to feature those interactions in a future newsletter.

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Announcements

MtnClim 2008



On the Way to Silverton, Ken Rockwell,
<http://www.kenrockwell.com>

The fourth mountain-climate conference sponsored by CIRMOUNT, this year's meeting will convene 9-12 June 2008 at Silverton, Colorado. The conference will feature three invited sessions on themes of adaptation to climate, drought and western mountain policy, and downscaled

modeling for mountain regions. Keynote lectures will be given by Mark Myers, Director of USGS, and Roger Barry, Director of the National Snow and Ice Data Center at the University of Colorado in Boulder. Kelly Redmond, Western Regional Climatologist at the Desert Research Institute, will present his always informative "MtnClim Climate-Year" talk on the ins and outs of weather during the past year in the West. Submissions of abstracts for oral and poster presentations on topics within CIRMOUNT's scope are invited to populate the contributed sessions.

Two field trips are planned for the weekend and day before MtnClim begins, including a visit to the Rocky Mountain Biological Lab in Gothic, CO, and a tour of local snow and climate monitoring sites operated by the Center for Snow and Avalanche Studies. Work Group meetings will again have the opportunity to meet prior to the main conference. A post-conference workshop for resource managers will focus on approaches for implementing adaptation strategies in field and natural-resource contexts.

Situated in the upper watershed of the Animas River, Silverton lies in the heart of the San Juan Mountains of southwest Colorado. With a population of 531 and elevation of 2836 m, Silverton exemplifies mountain communities of western North America where mining and harvest histories meet recreation and amenity uses of the present. Silverton is unusual as a small mountain town for being a center of activity in mountain climate sciences, with the Mountain Studies Institute (local host for MtnClim 2008) and the Center for Snow and Avalanche Studies (field tour host) located in town. Many mountain research studies from western universities are ongoing in the region, and local residents including resource managers, civic leaders, and the general populace, are avidly interested in climate science and its significance to local ecosystems and resource policy.

The deadline for registration and abstract submission is April 18, 2008 (see website). Silverton can be reached via commercial flights to several regional airports, including Durango, which is a 1-1/2 hour spectacular drive over several mountain passes. The historic Durango-Silverton Narrow Gauge Railroad offers a scenic alternative to driving. Rather than centralized conference lodging, participants will stay in town hotels, motels, and hostels, which offer a wide range of expense options.

The MtnClim conferences in general are dedicated to mountain-climate sciences, effects of climate variability on ecosystems, natural resources, and conservation, and the role of climate policy and management of mountain regions with a focus on western North America. The meetings are intended for all mountain scientists, natural resource and program managers, policy makers, and other interested professionals. Organizers and sponsors include the range of agencies and universities that coordinate CIRMOUNT as well as local hosts. We encourage presentation of work-in-progress, including innovative new directions or

controversial topics, and especially urge young scientists and students to offer abstracts. Registration is capped at 120 participants, with a goal of fostering serious science in a more informal setting than larger meetings can offer.

Past MtnClim conferences met at Lake Tahoe CA, Chico Hot Springs, MT, and Timberline Lodge Mt Hood, OR. For archives of those meetings, see: <http://www.fs.fed.us/psw/cirmount/meetings/archives.shtml>

MtnClim 2008 Organizers: Connie Millar (USFS), Henry Diaz (NOAA), Lisa Graumlich (Univ AZ) and the CIRMOUNT Coordinating Committee. For information on MtnClim 2008, contact Connie at cmillar@fs.fed.us or Henry at Henry.F.Diaz@noaa.gov.

Conference Website: <http://www.fs.fed.us/psw/mtnclim/>

Registration & Abstract Deadline: 18 April 2008

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

Fifth WMRS Regional Research Symposium: "Climate, Ecosystems, & Resources in Eastern California"



Increases in greenhouse emissions and other factors are bringing about climate change on a scale unknown in recorded human history. Wildland ecosystems are being directly and indirectly affected, and changes seem to be

accelerating. Mountain environments of the Sierra Nevada and western Great Basin ranges serve as key but threatened water towers that provide resources for downhill uses near and far. Because ecosystem services are necessary for activities such as tourism, outdoor recreation, water export and agriculture, the human economy of montane Eastern California will probably be profoundly affected. What form will climate change take in this region? What will be the nature of ecosystem responses to climate change? How will particular plant and animal species respond? How will ecosystem changes affect services on which the human economy depends? How can resource managers and local governments deal with these changes?

These and related topics will be the subject of a three-day symposium to be held November 5-8, 2008 in Bishop, California. We hope to share current research and thinking, so that scientists, resource managers, and the public will gain a better understanding of what is happening, and why. The symposium will include three broadly defined plenary sessions: climate and water, ecosystem responses, and adaptation & mitigation (management & policy). The morning plenary sessions will be followed by 10-15 concurrent sessions organized around themes relating to the central topics. There will be an opportunity for contributed talks as well as a poster session. Field trips may be offered, either before or after the symposium, and a keynote address will be open to the public free of charge. Please consult the following website for details and registration information: <http://www.wmrs.edu/projects/CEREC/announcement.htm>

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