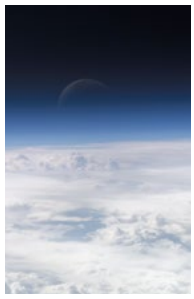
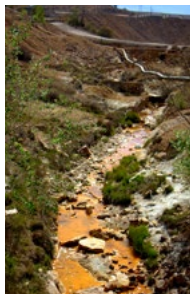
Southwest Climate Science Center

Annual Report 2015–16





2015/16

We are pleased to introduce the 2016 Annual Report for the Southwest Climate Science Center. The year marked the center's sixth anniversary and commenced the 18th year of severe drought in the Southwest, with continuing impacts across the region. The Southwest received some relief, with unusually high precipitation during the winter of 2016/2017, but it is too early to assess whether the meteorological drought is over. The hydrological drought continues, as witnessed by continued low water levels in the Colorado River's two largest reservoirs, Lakes Mead and Powell, and ecological impacts of the drought continue to reverberate. The scientific research, partnerships, and conversations with stakeholders have advanced climate adaptation across the region, but much work remains to be done.

This year's report features a number of milestones for the center. Particularly noteworthy is the initiation of the second phase of our collaboration with the Native Nations Climate Adaptation Program at the University of Arizona. The program, together with collaborations developed late in the year with the Bureau of Indian Affairs and the American Indian Higher Education Council, will put the center in a position to assist tribes across the Southwest in climate adaptation. We also partnered with the Landscape Conservation Cooperatives to co-convene a fall 2016 workshop to strengthen climate-related collaborations among on-the-ground stakeholders in the region. We continued supporting several projects that use the regional drought to better understand ecosystem responses to hot and dry conditions, and one of our ongoing projects led to an ambitious sediment-augmentation experiment at Seal Beach National Wildlife Refuge to explore how to offset sea-level rise in estuaries.

It's been our pleasure to work with the federal and university staff of the Southwest Climate Center, as well as with our diverse partners, collaborators, and stakeholders this past year. Going into 2017, we face challenges on a number of fronts, and we look forward to continuing to work within our broader community to devise and apply creative solutions.

Stephen T. Jackson
DIRECTOR (USGS)
SOUTHWEST CLIMATE SCIENCE CENTER

Jonathan Overpeck
DIRECTOR
SOUTHWEST CLIMATE SCIENCE CENTER
UNIVERSITY OF ARIZONA INSTITUTE OF ENVIRONMENT

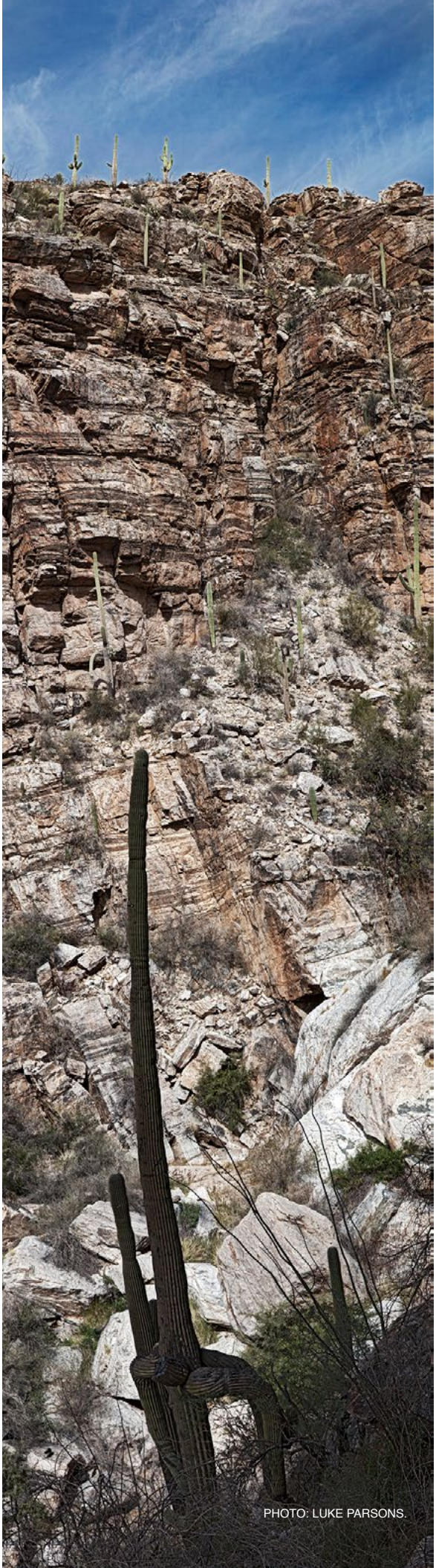


PHOTO: LUKE PARSONS.

1 Climate Science and Forecasting

The SW CSC develops knowledge of climate change and climate variability in the context of resource management. Decision makers need information that allows them to anticipate and plan across a range of time periods, from the coming months to the next century. Downscaling climate projections to make predictions at local scales must be accompanied by realistic assessments of uncertainty and will be most useful if managers and scientists reach a mutual understanding of the nature and intended applications of the downscaled estimates. Assessing how climate and other environmental phenomena might change over years to multiple decades represents a large but tractable challenge, particularly if scientific efforts concentrate on the temporal and spatial scales of central interest to stakeholders.

CENTRAL ARIZONA PROJECT. PHOTO: LILY HOUSE PETERS.

NATURAL VARIABILITY IN THE CHANGING CLIMATE: INTERACTION OF INTERANNUAL, DECADAL, AND CENTURY TIMESCALES WITH DAILY WEATHER AND A FOCUS ON EXTREME EVENTS (2013)

Principal Investigators: Alexander Gershunov and Dan Cayan (Scripps Institution of Oceanography)

Natural climate variability can either obscure or enhance long-term trends in regional weather. Natural variability is poorly described, which contributes to uncertainty and misunderstandings about the nature of climate change. The goal of this project is to clarify the effects of natural climate variability on the frequencies and intensities of specific extreme temperature and precipitation events and their cascading influences.

The research team developed an approach to summarize seasonal behavior of daily temperatures over the Southwest as well as a clear precipitation regime change signature. The U.S. Forest Service is using this work to understand how temperature change will affect the habitat of the California spotted owl. The resting metabolic rate of the owl increases substantially at temperatures warmer than 35.2 degrees Celsius, and behavioral responses to heat stress have been observed at temperatures from 30 to 34 degrees C. Projections for the end of the 21st century suggest that while there may be locations within their current habitat that remain cool enough for the owl species, their area could be reduced by 8 to 32 percent due to climate change.

For more information please visit: **WWW.SWCSC.ARIZONA.EDU/PROJECTS/NATURAL-VARIABILITY-CLIMATE**

HYDROLOGIC RESPONSE OF ATMOSPHERIC RIVER EVENTS IN THE SALT AND VERDE RIVER BASINS: CLIMATOLOGY AND POSSIBLE FUTURE CHANGES (2015)

Principal Investigators: Juan Valdes (University of Arizona) and Francina Dominguez (University of Illinois at Urbana-Champaign)

The Salt and Verde river basins in northeastern Arizona are a vital source of fresh water for the greater Phoenix metropolitan area and for two tribal reservations that rely on the basins' natural resources for their livelihood. Winter precipitation in this region is modulated by the occurrence of narrow river-like corridors of water vapor in the atmosphere, or atmospheric rivers (ARs), that replenish reservoirs, maintain natural ecosystem health, and alleviate droughts. However, these ARs also are linked to the basins' most intense storms, which can cause flooding, resulting in turbid waters that are not treatable for human consumption.

This project is examining how the hydrology of the Salt and Verde river basins have responded to extreme AR events in the past, how these events are affected by natural climate variability, and how they might be affected by future warmer temperatures. The project is giving natural resource managers and local tribes improved seasonal predictability and a better understanding of the possible changes that ARs might bring to their watershed as the result of climate change.

For more information please visit: **WWW.SWCSC.ARIZONA.EDU/PROJECTS/HYDROLOGIC-RESPONSE-SALT-VERDE**

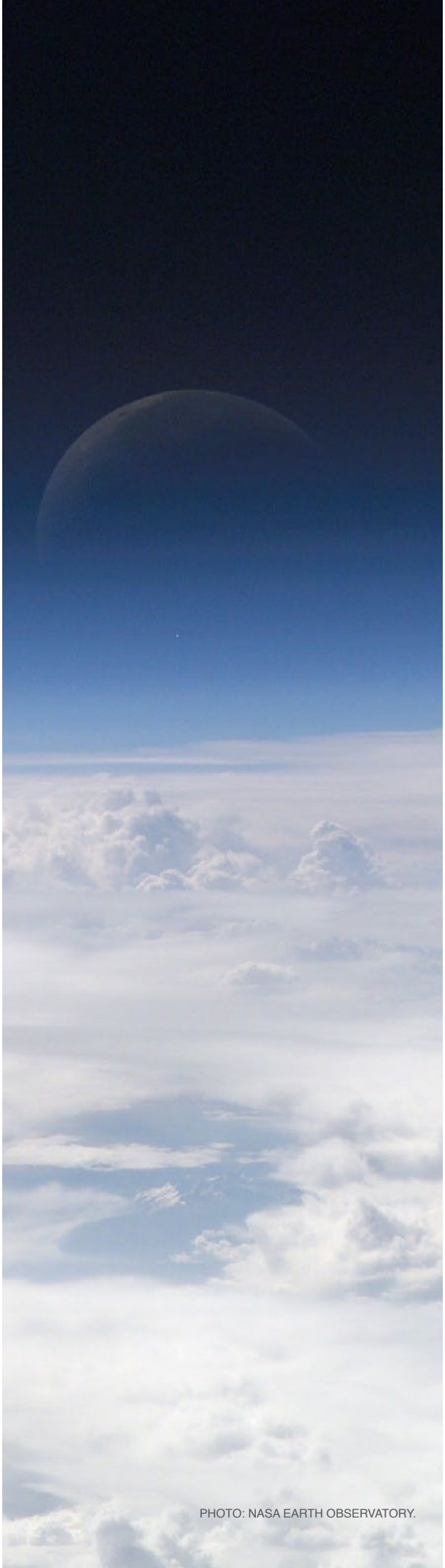


PHOTO: NASA EARTH OBSERVATORY.

2 Hydroclimate and Water Availability

Hydroclimate is affected by both precipitation and temperature and exerts control over water supply to rivers, lakes, wetlands, and groundwater. Hydroclimate also has major influences on terrestrial ecosystem structure, dynamics, and disturbance regimes from headwaters to coastal regions. Both climate extremes (for example, drought and flood) and long-term trends such as increasing temperature and earlier snowmelt not only alter habitat for terrestrial and aquatic animals, but also pose wildfire, flooding, and other threats to human habitations near the urban-wild land borders and to agricultural activities. Subtle interactions can have large effects, often in distant regions (for example, acceleration of snowmelt on mountain tops due to dust deposition from devegetated basins). Scientific knowledge can be incorporated into scenario planning, structured decision models, and other approaches to inform and engage stakeholders about a range of information, from vulnerability and risk assessments to crisis-management preparation.

COLORADO RIVER BASIN STREAMFLOW PROJECTION UNDER IPCC-CMIP5 SCENARIOS: FROM THE GLOBAL TO BASIN SCALE USING AN INTEGRATED DYNAMIC MODELING APPROACH (2013)

Principal Investigator: Christopher Castro (University of Arizona)

The Colorado River is the dominant water source for the Southwest. Recent climate change studies for the region project a dire future, with chronic drought and substantially reduced Colorado River flows. This project contains both regional climate and hydrologic modeling components designed to retrospectively diagnose and project streamflow in the Colorado River sub-basins, accounting for both natural variability and anthropogenic climate change.

The main objective of this project is to characterize how the changing climate of the Southwest is affecting cool- and warm-season precipitation in the Colorado River Basin and the corresponding response of streamflow in individual sub-basins. Basin-scale streamflow data for historic periods and future projections for the Salt, Verde, and Upper Colorado basins are available on the project website. This information is directly usable by water resource agencies such as the Central Arizona Project in their management planning tools. The research results also have motivated the Bureau of Reclamation to continue to work with the project team to use the data in other projects, including the assessment of climate change in the Lower Santa Cruz River basin.

For more information please visit: **WWW.SWCSC.ARIZONA.EDU/PROJECTS/COLORADO-RIVER-BASIN-STREAMFLOW**

LINKING INTERANNUAL VARIATIONS OF EXTREME STORMS WITH ECOLOGICAL AND HYDROLOGICAL DISTURBANCES IN THE SIERRA NEVADA (2014)

Principal Investigators: Christine Albano (Desert Research Institute) and Mike Dettinger (U.S. Geological Survey)

Atmospheric rivers are projected to increase in frequency and intensity as a result of climate change, with significant implications for people, infrastructure, and ecosystems. One key question is whether ARs can alter fire patterns by changing the amount of vegetation available as fuel. This question is critical because the Southwest is projected to experience more frequent and intense AR events in the future. To answer this question, researchers looked at historical AR events and analyzed the subsequent changes that occurred in vegetation growth and the size of wildfires.

Results show that ARs can increase the area burned by fires in the year following an event. The heavy precipitation that ARs bring increases soil moisture, which in turn spurs vegetation growth and temporarily inhibits fires. However, after a couple of months, the vegetation dries out and provides more fuel to feed fires than would normally be available, resulting in a larger wildfire season. The results of this project provide important insight into how wildfire fuel loads might change, enabling managers to better plan for future conditions and prioritize actions such as fuel load reduction following AR events.

For more information please visit: **WWW.SWCSC.ARIZONA.EDU/PROJECTS/LINKING-INTERANNUAL-VARIATIONS**

PHOTO: D. HARVEY.

EXAMINING THE INFLUENCE OF TEMPERATURE AND PRECIPITATION ON COLORADO RIVER WATER RESOURCES: RECONSTRUCTING THE PAST TO UNDERSTAND THE FUTURE (2014)

Principal Investigators: Connie Woodhouse (University of Arizona) and Greg Pederson (U.S. Geological Survey)

Climate projections for the Southwest show a future marked by chronic drought and reductions in available water supply. The region already has been impacted by a changing climate, with warmer temperatures and more intense droughts. While we know that precipitation has a major influence on streamflow, the role of temperature is less well understood. Findings from this study show that rising temperatures have been playing an increasingly important role in Colorado River streamflow in recent decades, amplifying the negative effects of drought and dampening the positive effects of wet winters.

Snow-fed rivers such as the Colorado rely heavily on winter precipitation. But warming temperatures since the 1980s have meant that less snow accumulates and snowpack melts earlier, both of which reduce streamflow. Though climate models have suggested that temperatures could affect streamflow, this study is the first to look at historical records to see if temperature has an effect. The researchers found that it does. Water managers are using this information to consider how water resources can be best managed under warming conditions. As such, they are gaining an awareness of the conditions they may expect in the future.

For more information please visit: **WWW.SWCSC.ARIZONA.EDU/PROJECTS/TEMPERATURE-PRECIPITATION-COLORADO-RIVER**

FEEDBACK INDEX FOR ASSESSING THE IMPACT OF RESTORATION ON ECOHYDROLOGICAL PROCESSES IN RESPONSE TO VARIABLE CLIMATE (2015)

Principal Investigators: Ty Ferré (University of Arizona) and Jesse Dickinson (U.S. Geological Survey)

Resource managers must balance the impacts of competing management decisions on multiple, interacting natural systems. Hydrologic and ecological processes, such as groundwater fluctuations and riparian evapotranspiration, can be tightly coupled. Ideally, managers would have tools and models that include all processes to better understand how each management action would propagate through the environment. The goal of this project is to develop a metric of hydrologic feedback strength for weighing the impact of conservation and restoration actions. Modeling and feedbacks will be used to quantify how hydrologic processes or restoration can amplify or absorb the effects of climate variability on riparian systems.

In tests with generalized systems, the team has found that the benefits of restoration actions can be unevenly distributed across watersheds. That is, a restoration action can increase the resilience in a certain area, but the action can exacerbate the vulnerability in other areas to changes from future climate. Their next steps are to apply the framework of feedbacks to the hydrological models of the Buenos Aires National Wildlife Refuge and San Bernardino National Wildlife Refuge.

For more information please visit: **WWW.SWCSC.ARIZONA.EDU/PROJECTS/RESTORATION-ECOHYDROLOGICAL-PROCESSES**

3 Ecological Responses and Vulnerabilities

Climate change and climate variability affect populations, species, communities, ecosystems, and landscapes across a wide range of scales and in a variety of ways. All ecosystems in the region, whether terrestrial, freshwater, coastal, or marine, may change in response to climate change. Understanding ecological consequences of climate change, anticipating how ecological responses will unfold under various future scenarios, and developing robust management strategies in response, is a major focus of the SW CSC.

INFLUENCE OF INTERANNUAL NORTH PACIFIC JET VARIABILITY ON SIERRA NEVADA FIRE REGIMES (2013)

Principal Investigator: Valerie Trouet (University of Arizona)

The position of the North Pacific Jet (NPJ), a high-altitude, narrow path of strong winds over the northern Pacific Ocean, is a key determinant of snowpack variability in California. The researchers' objectives for this project were to study NPJ climatology on decision-making timescales and to analyze the influence that the position of the NPJ has on Sierra Nevada fire regimes. Through the development of spatial and seasonal indices, the researchers reduced the vast complexity of the jet stream into variables that are useful to researchers and managers to link ecosystem dynamics to upper-level atmospheric patterns. The research is applicable to improving long-lead (weeks to months) forecasts of annual area burned, which is important for fire preparedness, anticipating fire suppression budgets, and scheduling prescribed fires. It is also important for evaluating the extent to which NPJ and regional annual fire occurrence has and will change due to anthropogenic warming.

For more information please visit: **WWW.SWCSC.ARIZONA.EDU/PROJECTS/NORTH-PACIFIC-JET-SIERRA-NEVADA-FIRE**

A COASTAL SITE NETWORK FOR ADVANCING UNDERSTANDING AND PREDICTION OF CLIMATE CHANGE EFFECTS ON NEARSHORE ECOSYSTEMS: INTEGRATING INTERDISCIPLINARY PROCESS STUDIES (2014)

Principal Investigator: Karen M. Thorne (U.S. Geological Survey) and Glen MacDonald (University of California, Los Angeles)

Salt marshes, mudflats, and shallow bays along the California coast support a wealth of natural resources and local communities. Rising sea levels and storm events threaten these habitats and their fish and wildlife, so understanding the consequences of future sea-level rise and climate change are necessary for planning, management, and restoration efforts in the future. Recovery of federally endangered salt-marsh species requires high-quality information to inform management decisions by multiple agencies.

This diverse research team has been examining these questions, working with resource managers to measure water level, salinity, temperature, and surface elevation at a network of coastal sites. They have also deployed experiments and measurements to examine site-specific ecological responses to inundation in order to inform decision making on the ground. The researchers have engaged directly with more than 100 resource managers from federal and state agencies and local and regional organizations. This work has been integrated into planning and educational documents by multiple organizations. It also has led directly to a decision by the U.S. Fish & Wildlife Service (USFWS) to conduct a sediment augmentation pilot project at Seal Beach National Wildlife Refuge, aimed at increasing marsh elevation and making endangered species habitat more resilient to sea-level rise and storm events.

For more information please visit: **WWW.SWCSC.ARIZONA.EDU/PROJECTS/COASTAL-SITE-NETWORK**

LEAF TO LANDSCAPE: UNDERSTANDING AND MAPPING THE VULNERABILITY OF FORESTS TO HOTTER DROUGHTS (PG.16). RESEARCHERS EMILY FRANCIS, KOREN NYDICK, AND ANTHONY AMBROSE DISCUSS REMOTE SENSING RESULTS COMPARED TO FIELD CONDITIONS. PHOTO: WENDY BAXTER, UNIVERSITY OF CALIFORNIA AT BERKELEY.

HOW DOES CLIMATIC STRESS AT INTERMEDIATE TIMESCALES INFLUENCE FIRE SEVERITY? (2014)

Principal Investigators: Phillip van Mantgem (U.S. Geological Survey) and Donald Falk (University of Arizona)

Drought and fire are two well-known hazards expected to increase in the Southwest in an era of climate change. Might the effects of drought and fire combine to cause even greater risks for southwestern forests in the future? This research tries to solve part of this puzzle by discovering how drought might weaken trees leading to increased tree death following fires. It is important to understand how drought and fire might work together to cause tree death. More frequent tree deaths will mean compromised wildlife habitat, increased erosion, and greater carbon emissions following fires across the Southwest.

The research team worked with the National Park Service using existing data coupled with tree-ring analyses and detailed climate data to determine how all these factors fit together in recent fires. Their results show that resistance to fire was significantly influenced by climate, fire injury, and region, noting that resistance to fire is sensitive to drought conditions in both the pre- and post-fire periods. Whereas resilience to fire was influenced by climate, pre-fire growth trends, and time since fire. Resilience was more negatively affected by climatic water deficit than resistance was.

For more information please visit: **WWW.SWCSC.ARIZONA.EDU/PROJECTS/CLIMATIC-STRESS-FIRE-SEVERITY**

PHOTO: USFS COCONINO NATIONAL FOREST.

IMPACT OF DROUGHT ON WATERBIRD WETLAND HABITATS, BIOENERGETICS, AND MOVEMENTS IN THE CENTRAL VALLEY OF CALIFORNIA (2015)

Principal Investigators: Joseph Fleskes (U.S. Geological Survey) and Matthew Reiter (Point Blue Conservation Science)

Wetland managers in the Central Valley of California require information regarding the amount and location of existing wetland habitat to make decisions on how to best use water resources to support multiple wildlife objectives, particularly during drought. Scientists from the USGS (U.S. Geological Survey) Western Ecological Research Center, Point Blue Conservation Science, and the USFWS are partnering to learn how the flooded wetland habitats, which are often agricultural lands used by waterfowl and shorebirds, change through the year. During extreme drought conditions, the ability to provide sufficient water for wildlife often depends on the timing of water deliveries and decisions whether to fallow croplands. Waterfowl and shorebirds may be particularly affected by these decisions because they typically rest and feed in flooded habitats. Poor habitats resulting from improper water deliveries could reduce waterfowl hunting opportunities and body condition. The research team is developing near real-time tracking of waterbird habitats and connecting it with near real-time tracking of waterfowl throughout the valley to learn which habitats the birds use and why. This information is being used to show how wetlands can be managed to provide the best possible habitat for waterbirds, even during extreme drought.

For more information please visit: **WWW.SWCSC.ARIZONA.EDU/PROJECTS/WATERBIRD-WETLAND-HABITATS**

RELATIONS AMONG CHEATGRASS-DRIVEN FIRE, CLIMATE, AND SENSITIVE-STATUS BIRDS ACROSS THE GREAT BASIN (2015)

Principal Investigator: Erica Fleishman (University of California, Davis)

As the distribution and abundance of non-native cheatgrass in the Great Basin has increased, the extent and frequency of fire in the region has increased by as much as 200 percent. These changes in fire regimes are associated with loss of sagebrush and other native grasses and shrubs in which many native animals, including the greater sage-grouse, breed and feed. This project is modeling current and future spatial interactions among cheatgrass cover and biomass, precipitation, and fire across the Great Basin and is modeling current and future cover of sagebrush and other herbaceous vegetation. The research team also is examining projected changes in fire regimes and fire and fuel treatments that may affect habitat quality for and probability of occupancy of sensitive-status breeding birds.

In order to make the results of this project the most useable, the team is engaging managers at local, state, and regional levels, and involving both field-level and director-level personnel, during all stages of the project. They are conducting field visits, workshops, and interactive briefings to build trust and increase the likelihood of informing management actions during the project period and beyond.

For more information please visit: **WWW.SWCSC.ARIZONA.EDU/PROJECTS/CHEATGRASS-DRIVEN-FIRE**

FIGHTING DROUGHT WITH FIRE: CAN MANAGERS INCREASE FOREST RESISTANCE TO DROUGHT USING PRESCRIBED FIRE? (2015)

Principal Investigators: Phillip van Mantgem (U.S. Geological Survey) and Donald Falk (University of Arizona)

Drought kills trees either directly or by making them more vulnerable to pests and pathogens. Although reduced precipitation defines drought, high temperatures lead to increased evaporative loss from plants and soil that amplifies drought stress in what is called "hotter drought." Many state and federal land-management agencies in the Southwest support large prescribed fire programs aimed at reducing understory fuels and forest density. Resource managers also assume that prescribed fire reduces competition among the surviving trees, making them more resistant to drought and other stressors.

This project uses the ongoing, severe drought across the Southwest as a natural experiment to determine whether prescribed fire in fact helps trees survive drought stress. The researchers compared drought-related tree mortality in burned and unburned sites in Kings Canyon, Sequoia, and Yosemite national parks to see whether the trees in the burned sites were more resistant to drought stress. Early results show that current prescribed-fire practices did in fact increase forest resistance to drought. Managers at Sequoia and Kings Canyon national parks have used these results to expand prescribed fire operations. The researchers are continuing to work with forest managers across the region to help guide forest management practices to increase forest resistance to the hotter droughts that the region is likely to experience in coming years and decades.

For more information please visit: **WWW.SWCSC.ARIZONA.EDU/PROJECTS/FIGHTING-DROUGHT-WITH-FIRE**

CAN MANAGEMENT INCREASE FOREST RESISTANCE TO DROUGHT? (2015)

Principal Investigators: James Thorne (University of California, Davis) and Phillip van Mantgem (U.S. Geological Survey)

The San Joaquin region of Southern California is currently undergoing the most severe drought in its recorded history. In the central and southern Sierra Nevada, federal land managers are scrambling to respond to this event, but they lack information needed to make informed decisions. It is assumed that removing small trees using a combination of mechanical thinning and/or prescribed fire will result in reduced competition for water and light and allow the remaining trees to be more resistant in the face of stressors, such as drought. Yet this proposition remains largely untested. This project is integrating extensive field data with remote sensing and Geographic Information Systems to inform this key management decision for forest climate change adaptation.

The research team conducted stakeholder outreach to make sure their science is actionable. They sought advice from their stakeholder collaborators on what the most useful formats for the final products should be in order to incorporate them into ongoing management planning. The primary suggestion from stakeholders was for them to process as many of the hyperspectral flight lines as possible, so that any locations that fall within the flight boxes could be compared, thereby making the resulting data products useful to a wider range of collaborators.

For more information please visit: **WWW.SWCSC.ARIZONA.EDU/PROJECTS/FOREST-RESISTANCE-DROUGHT**

LEAF TO LANDSCAPE: UNDERSTANDING AND MAPPING THE VULNERABILITY OF FORESTS TO HOTTER DROUGHTS (2016)

Principal Investigators: Koren Nydick (National Park Service), Greg Asner (Carnegie Airborne Observatory), and Todd Dawson (University of California, Berkeley)

Forests across the southwestern U.S. are crucial components of recreation and play an important role in state and local economies. Healthy forests also provide habitat for many wildlife species and contribute many other important services to our planet. The so-called hotter droughts are an emerging climate change threat to forests, including those in the Southwest. The Leaf to Landscape project uses California's unusually hot drought as a potential preview of the future, allowing the research team to collect information that will help guide forest management in the face of a warming climate.

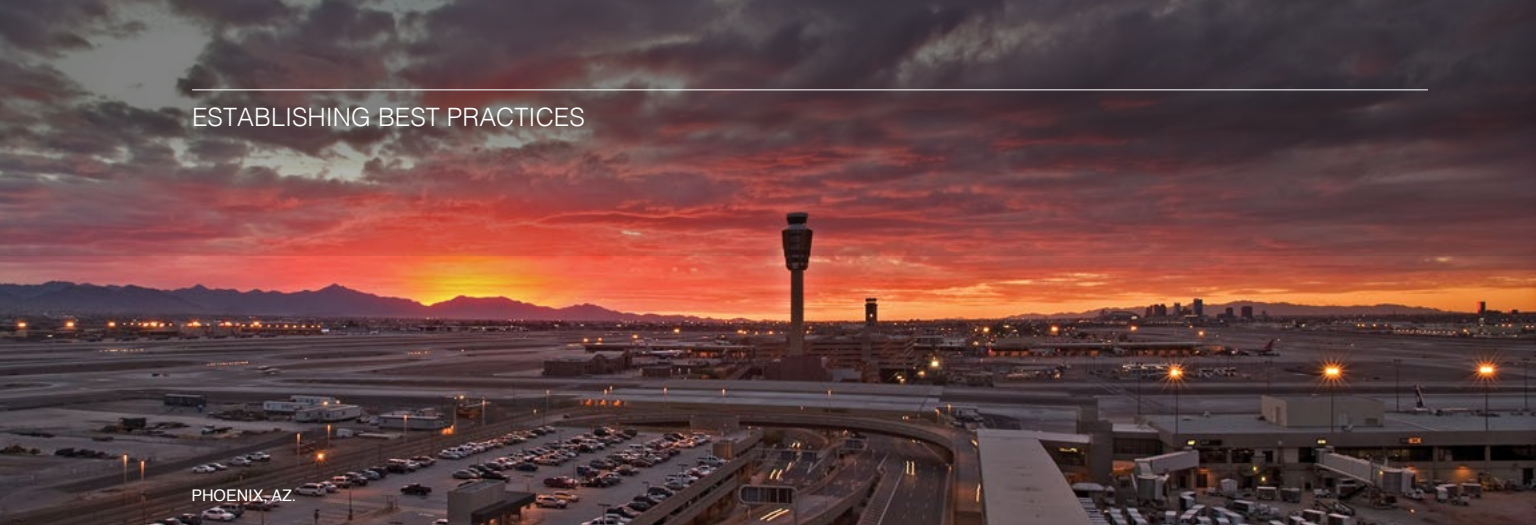
This project seeks to understand the effects of the hotter drought on Sierra Nevada forests across three different spatial scales (from leaves to landscapes): (1) water stress and the physiology of individual trees; (2) measurements of foliage dieback and tree mortality in tree populations; and (3) large landscape mapping of the vulnerability of forests to drought using airborne sensors. Linking the findings across these scales will help forest managers better understand the thresholds of forest stress and dieback—including for the iconic giant sequoias —and how and why these thresholds vary across landscapes. Important products will include maps of forest vulnerability to hotter droughts of the future. These results will help forest managers target forest treatments, such as prescribed fire, that are aimed at increasing the likelihood that forests will persist in the face of future climatic changes.

For more information please visit: **WWW.SWCSC.ARIZONA.EDU/PROJECTS/LEAF-TO-LANDSCAPE**

PHOTO: LILY HOUSE PETERS.

4 Establishing Best Practices

Perhaps the most important challenge in climate adaptation is reconciling the information needs of stakeholders with available scientific knowledge and capacities. This is not so much a technical challenge as a fundamental challenge in communication and mutual understanding among different communities. Identifying best practices for engagement between research and stakeholder communities is a principal crosscutting theme for the SW CSC.



PHOENIX, AZ.

DEVELOPMENT, DELIVERY, AND APPLICATION OF DATA ON CLIMATE EXTREMES FOR THE SOUTHWESTERN UNITED STATES (2014)

Principal Investigators: Erica Fleishman (University of California, Davis) and Alexander Gershunov (Scripps Institution of Oceanography)

This project seeks to improve estimates of extreme temperature and precipitation, evaluate the responses of natural resources to climate extremes, and make it easier to obtain customized climate information for all parts of the Southwest. Extreme climate can have substantial effects on endangered species, such as the Mojave desert tortoise, and on non-native invasive species such as cheatgrass. Changes in extreme temperature and precipitation also are likely to affect the health of people who use or visit public lands. By 2100, droughts of 10 or more years are likely to become more frequent. There are likely to be fewer wet days per year, and more precipitation on those few wet days also is more likely.

This work is examining how such precipitation extremes may affect numerous ecological processes, from stream flow to fire. The research team is improving a web-based platform (SCENIC - wrcc.dri.edu/csc/scenic) that allows users to obtain data from weather stations across the region or from climate models and provide guidance on which models best represent different climate patterns or events across the Southwest. Their work will inform decision making by private landowners, public agencies, and managers of diverse natural resources.

For more information please visit: **WWW.SWCSC.ARIZONA.EDU/PROJECTS/CLIMATE-EXTREMES-SOUTHWEST**

PRODUCING IMPACTFUL SCIENCE: THE EFFECT OF STAKEHOLDER ENGAGEMENT STRATEGIES ON THE USE OF CLIMATE SCIENCE IN MANAGEMENT DECISIONS (2015)

Principal Investigators: Alison Meadow (University of Arizona) and Tamara Wall (Desert Research Institute)

In order for science to have the most impact on resource management, it needs to directly address the questions that managers and other stakeholders have. Essentially, the ways in which researchers and resource managers collaborate can affect the use of scientific information in decision making. Previous research has shown that relatively more collaboration between researchers and resource managers tends to lead to more effective use of new scientific information. However, good ways to evaluate these research processes or the outcomes we expect them to produce do not yet exist.

This project is assessing the key variables necessary for the successful production of usable climate information. To do so, researchers are evaluating the collaborative science approach currently being implemented in a project on managing forests for drought in California. Researchers are interviewing the project's scientists about their goals and stakeholder engagement approaches; observing meetings between scientists and managers; interviewing both scientists and managers at the conclusion of the project to identify the level of satisfaction with the approach used; and interviewing managers six months later to follow up on how the information was actually used in decision making. The results of this project will help inform best practices for scientists to engage stakeholders during the research process. Identifying the best strategies for stakeholder engagement is essential for ensuring that the science produced is usable and valuable for decision makers.

For more information please visit: **WWW.SWCSC.ARIZONA.EDU/PROJECTS/PRODUCING-IMPACTFUL-SCIENCE**

5 Tribal Engagement

Native Nations have historically adapted to their environment, yet today they face unique challenges linked to climate change. Native Americans have a deep connection to the natural environment within which their livelihoods, cultural identity, and ceremonial practices are rooted. Changes to water systems, landscapes, and ecosystems, in combination with socio-economic and political factors, amplify tribal vulnerabilities to climate change. With more than 200 federally recognized tribes in the region, tribal communities and tribal resource managers are a key group of stakeholders for the SW CSC.

KARLETTA CHIEF.PHOTO: RAINA RAMIREZ.

Tribal Climate Science Liaison

With funding from the Bureau of Indian Affairs, the SW CSC partnered with the American Indian Higher Education Consortium to support a tribal climate science liaison to develop communications between the SW CSC and regional tribes, provide technical support to tribes, aid in the creation of climate adaptation plans, and coordinate regional workshops. The position, which aids the SW CSC in its initiative to build tribal resilience to climate change, has been filled by Holly Barton, who is a member of the Navajo Nation.

Tribal Engagement Projects and Program Investments

PYRAMID LAKE PAIUTE TRIBE TRADITIONAL KNOWLEDGE AND CLIMATE CHANGE ADAPTATION (2016)

Principal Investigator: Karletta Chief (University of Arizona)

Climate change may overwhelm tribes already stressed by economical and development challenges. A primary example is Nevada's largest tribe, the Pyramid Lake Paiute Tribe (PLPT), who are culturally, physically, and spiritually connected to Pyramid Lake at the terminal end of the Truckee River Basin and its ecosystem.

The research team's previous research indicates that PLPT is an exemplary leader in adaptive planning, given that tribal members are keenly aware of and concerned for climate change impacts to Pyramid Lake. Climate adaptation that considers traditional knowledge and livelihoods of tribal members is critical to successful adaptation for PLPT. The researchers are conducting interviews and focus groups with community members to better understand the role of traditional knowledge in PLPT culture and its potential use in climate adaptation. This collaborative research addresses the need for climate change adaptation research in the U.S. that incorporates tribal perspectives and can offer insight for adaptation planning efforts among other tribes.

For more information please visit: **WWW.SWCSC.ARIZONA.EDU/PROJECTS/PYRAMID-LAKE-PAIUTE-TRIBE**

NATIVE NATIONS CLIMATE ADAPTATION PROGRAM DEVELOPMENT PHASE 1: TRIBAL ADAPTATION INITIATIVE LAUNCH (2015)

Principal Investigator: Katharine Jacobs (University of Arizona)

The University of Arizona's Center for Climate Adaptation Science and Solutions (CCASS) partnered with the SW CSC to leverage previously existing and newly developing tribal engagement capacity through the Native Nations Climate Adaptation Program (NNCAP). NNCAP conducted a preliminary assessment of tribal interest and capacity for adaptation across the Southwest through interviews with selected tribal leaders and resource managers in an effort to identify emergent opportunities that support tribes in adapting to climate change. In November 2015, NNCAP also partnered with the Desert Landscape Conservation Cooperative (LCC) to hold a meeting with tribal members that focused on successful tribal climate adaptation plans, lessons learned, traditional ecological knowledge, and tribal adaptation activities across the U.S.

For more information please visit: **WWW.SWCSC.ARIZONA.EDU/PROJECTS/TRIBAL-ADAPTATION-AND-SCENARIO-PLANNING**

NATIVE NATIONS CLIMATE ADAPTATION PROGRAM DEVELOPMENT PHASE 2: BUILDING PARTNERSHIPS TO INCREASE TRIBAL CAPACITY FOR CLIMATE CHANGE ADAPTATION PLANNING (2016)

Principal Investigator: Katharine Jacobs (University of Arizona)

NNCAP is building on the success of the 2015 project and is strengthening partnerships to support the climate adaptation capacity of tribes in the Southwest. NNCAP is identifying collaborative networks among researchers, tribal members, and other partners and is supporting outreach and extension work related to tribes in climate adaptation planning and implementation. NNCAP is also planning to build on their 2015 meeting and hold a second meeting with adaptation practitioners who specialize in tribal climate adaptation to share experiences, build capacity, promote collaboration, and share best practices among several groups.

For more information please visit: **WWW.SWCSC.ARIZONA.EDU/PROJECTS/INCREASE-TRIBAL-CAPACITY**

LEFT: HUNTER LAKE ELEMENTARY SCHOOL FIELD TRIP TO PYRAMID LAKE PAIUTE TRIP MUSEUM IN NIXON, NV. PHOTO: BLACK ROCK SOLAR.

ROAD WASHED OUT DUE TO FLOODING:PHOTO: ©JOHN WARK/AP/CORBIS.

6 Scenario Planning: in theory and practice

In collaboration with the Center for Climate Adaptation Science and Solutions, the SW CSC co-organized a series of workshops aimed at understanding the diverse landscape of scenario planning approaches and identifying approaches best suited to specific conservation and management contexts. This effort is building capacity for more effective management under climate change and refining an important set of decision-support tools for adaptive management.

Scenario Planning Projects

SUPPORT FOR ENHANCED SCENARIO PLANNING OUTCOMES (2015)

Principal Investigator: Katharine Jacobs (University of Arizona)

Decision makers and natural resource managers are increasingly being asked to make decisions in the context of uncertainty, with climate change adding new sources of complexity. Scenario planning approaches are being used as a means of providing managers with insights into options for responding appropriately to change in the near and long term. A workshop held at the University of Arizona in April 2015 brought together a group of 30 experts and practitioners to explore two things: (1) lessons learned in applications of a variety of specific scenario planning techniques, and (2) connections between the different methods that have emerged relative to how they frame uncertainty and how they function in a decision-support context.

In a second, smaller workshop in December 2015, the team scoped the production of a range of outputs that include a broader toolkit of scenario methods and techniques for decision makers and improved connections with local and regional planners; practical suggestions for practitioners on how to use these techniques and in what combinations; a list of research, institutional, and resource needs to improve the information available and the flow of information across methods in specific applications; and curriculum development and training opportunities.

For more information please visit: **WWW.ADAPTATIONSCENARIOS.ORG**

SUPPORTING CONSERVATION PLANNING FOR LANDSCAPES IN THE SOUTHWEST (2016)

Principal Investigator: Matt Grabau (Desert Landscape Conservation Cooperative)

Changes in temperature and precipitation due to climate change (and associated droughts, wildfires, extreme storms, etc.) threaten important water sources, forests, wildlife habitat, and ecosystems across the Southwest. These threats cross political and man-made boundaries and therefore need to be addressed at larger landscape-level and regional scales. Landscape conservation design is one method that can be used by land and resource managers to support large-scale conservation and ensure that small-scale and local actions contribute to a landscape-level vision. The Desert Landscape Conservation Cooperative is working to develop a shared vision for conservation action in the Southwest through a collaborative process to identify shared conservation goals, stressors, and vulnerabilities across Southwest landscapes and potential management responses to changing climatic conditions.

Through this project, the SW CSC is supporting the Desert LCC in its efforts to collect data and information about important Southwest resources, create scenarios of the future that include the effects of climate change and other landscape stressors on important resources, and develop a list of possible collaborative adaptation responses that are useful and implementable by partners. The Desert LCC is facilitating broad stakeholder participation in the landscape conservation design process in pilot areas across the Southwest and is hosting initial workshops to bring together regional partners to incorporate existing information and ideas into a current assessment of resource conditions. The Desert LCC will use these workshops to develop reports that will include a prioritization of science needed to support future landscape conservation design work and recommendations for filling these information gaps.

For more information please visit: **WWW.SWCSC.ARIZONA.EDU/PROJECTS/SUPPORTING-CONSERVATION-PLANNING**

PHOTO: CALIFORNIA DEPARTMENT OF WATER RESOURCES

7 Translational Ecology

Decision makers frequently express frustration that scientists provide answers to the wrong questions or otherwise fail to address their information needs in the contexts in which decisions are made. Moreover, researchers often default to one-way communication, focusing their attention on how to improve their 'messaging.' Modeled after translational medicine by requiring "constant two-way communication between stakeholders and scientists," translational ecology aims to facilitate the development of actionable, decision-relevant science. This parallels recent work focused on the practice of knowledge coproduction, particularly in the context of climate adaptation. Coproduction refers to strong collaborations between scientists and decision makers during all phases of research, from project inception to preparation of research products, and through iterative interactions to address emerging research and information needs.

TRANSLATIONAL ECOLOGY

The SW CSC is leading an effort to explore and articulate the theory and practice of translational ecology. A diverse working group is giving special focus to understanding past successes and failures in scientist-stakeholder engagements, seeking solutions to critical barriers and challenges in knowledge coproduction, and summarizing best practices for translational ecology.

Translational Ecology Working Group

Leaders: Stephen T. Jackson, (U.S. Geological Survey), Carolyn AF Enquist (U.S. Geological Survey), and Gregg Garfin (University of Arizona)

Mark Brunson (Utah State University)

Frank Davis (University of California, Santa Barbara)

Leah Gerber (Arizona State University

Kim Hall (The Nature Conservancy)

Lauren Hallett (Oregon State University)

Ben Halpern (University of California, Santa Barbara)

J. Kevin Hiers (Tall Timbers Research Station and Land Conservancy)

Dawn Lawson (U.S. Department of the Navy)

Jeremy Littell (Alaska Climate Science Center, USGS)

Elizabeth McNie (University of Colorado, Western Water Assessment)

Toni Lyn Morelli (Northeast Climate Science Center, USGS)

Max Moritz (University of California, Berkeley)

Koren Nydick (National Park Service)

Amber Pairis (California Department of Fish and Wildlife)

Andrea Ray (National Oceanic and Atmospheric Administration)

Claudia Regan (USGS)

Hugh Safford (US Forest Service)

Mark Schwartz (University of California, Davis)

Rebecca Shaw (World Wildlife Fund)

Nate Stephenson (USGS)

Jennifer Tank (University of Notre Dame)

Adam Terando (SE CSC, USGS)

Tamara Wall (Desert Research Institute)

Matt Williamson (University of California, Davis)

Connie Woodhouse (University of Arizona)

Laurie Yung (University of Montana)

For more information please visit:
WWW.SWCSC.ARIZONA.EDU/TRANSLATIONAL-ECOLOGY

BIG SUR COAST OF CALIFORNIA. PHOTO: RON AND PATTY THOMAS.

8 Regional Climate Program Coordination

The SW CSC has taken the initiative to co-organize and foster discussions among regional climate adaptation entities, including DOI CSCs and LCCs, NOAA RISAs, and USDA Climate Hubs, NGOs, and state and local agencies. Activities include symposia and panels at the National Adaptation Forum, Climate Predictions Application Science Workshop, and American Geophysical Union Meeting. These discussions are fostering coordination and utilization of existing capacity more effectively for scientist-decision maker communication and are identifying critical gaps and needs in climate adaptation capacity.

Most recently, the SW CSC co-organized a workshop with four LCCs to identify shared objectives and cultivate collaborations among conservation entities working across California. A workshop report and action items are forthcoming.

For more information please visit:
WWW.CALIFORNIALCC.ORG/JOINT-LCC-CSC-MEETING

2016 Stakeholder Advisory Committee meeting

University of Arizona, April 2016

The needs of regional resource managers inform the science that the SW CSC plans, supports, and conducts. The Stakeholder Advisory Committee (SAC), comprised of federal, state, and tribal representatives from across the Southwest, met in April 2016 to share information and facilitate cooperation. Representatives from the California, Desert, and Southern Rockies LCCs attended, as did members from the National Park Service, U.S. Forest Service, Southwest Climate Hub, Bureau of Reclamation, Department of the Navy, Bureau of Land Management, U.S. Fish and Wildlife Service, and Tohono O'odham Nation. Reports back from the meeting indicated that the SW CSC was doing great research and on the right path for stakeholder engagement.

43rd Annual Natural Areas Conference

University of California, Davis, October 2016

Symposium Title: Forests in the oven (Part 2): Implications of hotter drought for forests and their management in California and across the U.S.

Ongoing hotter drought—drought accompanied by warmer temperatures—has triggered tree mortality and widespread forest dieback across California, the broader Southwest, and elsewhere. A rapid increase in research over the past decade has revealed that forests and the ecosystem services they provide will face high levels of vulnerability as climate continues to warm. Moreover, the risk of large-scale ecosystem transformation is particularly worrisome, resulting from the synergies between hotter drought, extreme precipitation events, flooding, and land-use change. As a follow up to the the 2015 Southwest Climate Summit, this session provided an overview of recent scientific advances by researchers from the West at-large, the Southeast, and Northeast, but with special focus on California. A diverse panel of speakers gave relevant updates in the context of forest management and engaged the audience in a closing group discussion.

PHOTO: DAN SHERWOOD@CORBIS.

SCENIC

The web interface, SCENIC (**WRCC.DRI.EDU/CSC/SCENIC**), which allows environmental scientists to access and analyze climate data, is under development in collaboration with the SW CSC and the Western Regional Climate Center. It serves as an access point for climate data and analysis tools for the Southwest as well as the rest of the contiguous U.S. Several analysis and visualization tools are available to help resource managers in the decision-making process. Among these are tools to summarize data, identify extremes, generate custom time series graphs, and generate climate summary tables. The site is currently being tested for usability and is being refined as more stakeholders and scientists use it and provide feedback.

LOCA

LOCA is a next-generation climate modeling dataset with improved local-scale climate projections that covers northern Mexico to southern Canada for the 21st century. It was developed through a collaboration of university researchers, government agencies, and private sector groups with support from SW CSC researchers.

The dataset was produced by researchers at Scripps Institution of Oceanography at the University of California, San Diego, who developed a new climate downscaling method for global climate models known as localized constructed analogs or LOCA. Global climate model pixels can be 100 miles across, which is too broad to study impacts of climate change at the local level. LOCA downscaled climate projections provide temperature and precipitation on pixels that are six kilometers across. LOCA also attempts to better preserve extreme hot days and heavy rain events, regional patterns of precipitation, and the future climate changes predicted by the global climate models.

9 Capacity Building

An essential part of the SW CSC mission is training the next generation of climate scientists. SW CSC-funded projects provide an essential training ground for graduate students, doctoral students, and postdoctoral researchers to work with and learn from leading climate science researchers.

Postdoctoral Researchers:

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Flurin Babst, University of Arizona

Soumaya Belmecheri, University of Arizona

Margarita Huesca, University of California, Davis

Teresa Krause, SWCSC,USGS

Suraj Polade, Scripps Institution of Oceanography

Sophie Webber, University of California, Los Angeles

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Becky Brice, University of Arizona

Lauren Brown, University of California, Los Angeles

Carlos Carillo, University of Arizona

Schuyler Chew, University of Arizona

Jesse Dickinson, USGS

Frank Fogarty, University of California, Davis

Huancui Hu, University of Illinois

Rajarshi Mukherjee, University of Arizona

Lynn Rae, University of Arizona

Jordan Rosencranz, University of California, Los Angeles

Yareli Sanchez, University of California, Los Angeles

Robert Shepard, University of Arizona

Itinderjot Singh, University of Illinois

Matt Williamson, University of California, Davis

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