Department of the Interior

U.S. Geological Survey

Southwest Climate Science Center

DRAFT 2013 Strategic Science Agenda

Southwest Climate Science Center

USGS science for a changing world

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Acronyms Used in this Report

ASU	Arizona State University
CSC	Climate Science Center
CU	University of Colorado
DOI	U.S. Department of the Interior
DRI	Desert Research Institute
NCCWSC	National Climate Change and Wildlife Science Center
LCC	Landscape Conservation Cooperative
NASA	National Aeronautical and Space Administration
NAU	Northern Arizona University
NGO	non-governmental organization
NOAA	National Oceanic and Atmospheric Administration
SAC	Stakeholder Advisory Committee
SIO	Scripps Institution of Oceanography
SWCA	Southwest Climate Alliance
SW CSC	Southwest Climate Science Center
UA	University of Arizona
UCD	University of California - Davis
UCLA	University of California - Los Angeles
UCM	University of California - Merced
UNLV	University of Nevada - Las Vegas
USFS	U.S. Forest Service
USGS	U.S. Geological Survey

Introduction

The Department of the Interior (DOI) recognizes and embraces the unprecedented challenges of maintaining our Nation's rich natural and cultural resources in the 21st century. The magnitude of these challenges demands that the resource-management community work together to develop integrated adaptation strategies that collectively address the impacts of climate change and other landscape-scale stressors. On September 14, 2009, DOI Secretary Ken Salazar signed Secretarial Order 3289 (amended February 22, 2010), entitled "Addressing the Impacts of Climate Change on America's Water, Land, and Other Natural and Cultural Resources." The Order establishes the foundation for two partner-based conservation science entities to address these unprecedented challenges: Climate Science Centers (CSCs) and Landscape Conservation Cooperatives (LCCs). CSCs and LCCs are the Department-wide approach for applying scientific tools to increase understanding of climate change and to coordinate an effective response to its impacts on American Indian tribes and the land, water, ocean, fish and wildlife, and cultural-heritage resources that DOI manages. Eight CSCs have been established and are managed through the U.S. Geological Survey (USGS) National Climate Change and Wildlife Science Center (NCCWSC); each CSC closely collaborates with neighboring CSCs and those across the Nation to ensure that scientific knowledge is produced and delivered efficiently. The role of the CSCs is to provide stakeholders, including the LCCs, with the scientific knowledge and tools needed for adaptation to climate change, which requires the sharing of resources and information across institutional and organizational boundaries.

The Southwest CSC (SW CSC) was established in 2011 to address the regional resource management challenges presented by climate change and variability in the southwestern United States (fig. 1). The focus of the SW CSC is on developing and communicating essential scientific knowledge and tools to benefit the region's managers of land, water, wildlife, and cultural resources. Although the SW CSC is primarily concerned with the southwestern United States, it will collaborate with other CSCs across the nation to develop national capabilities and address regional challenges in an integrated fashion.

The Strategic Science Agenda identifies the region's key climate-science needs and the SW CSC's mission and goals, communication strategies, scientific priorities, and needed expertise for the next 3 to 5 years. Annual science workplans that define specific actions will supplement this science agenda.

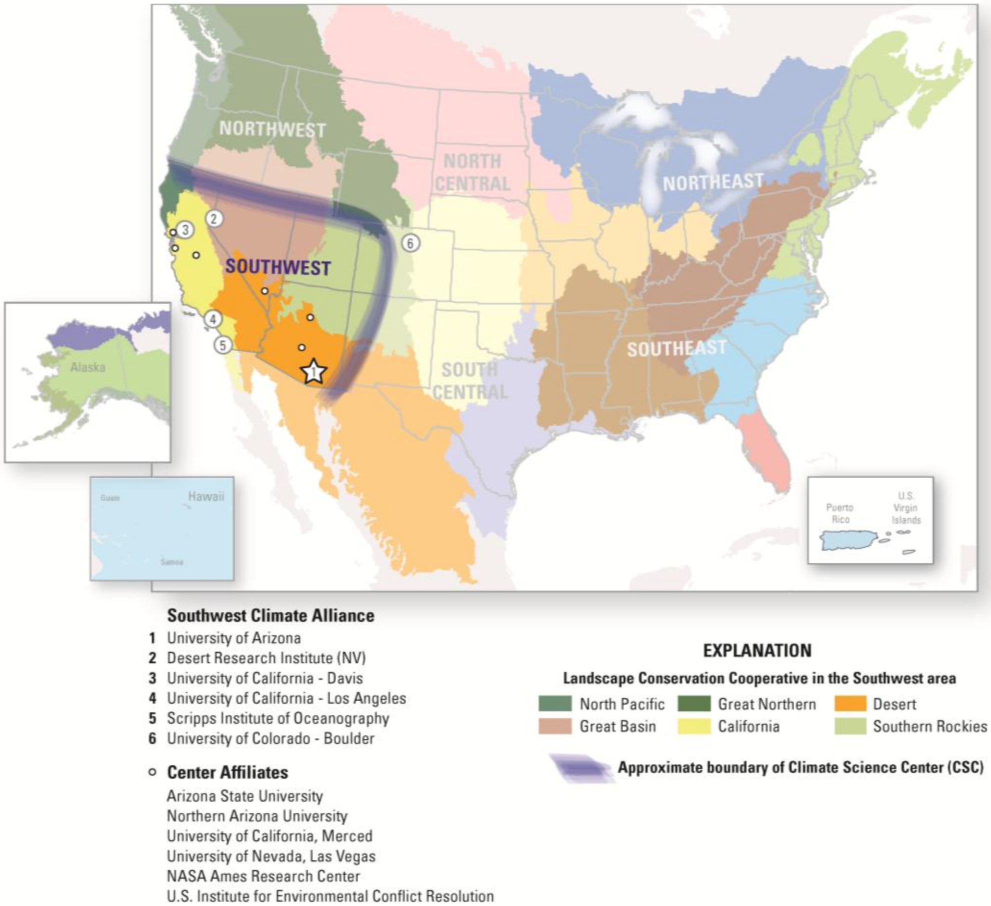

Figure 1. Focus area for the Southwest Climate Science Center and the boundaries of the Landscape Conservation Cooperatives.

The SW CSC, like each of the CSCs, is partnered with academic institutions within and around the region – collectively referenced as the Southwest Climate Alliance (SWCA) – to leverage expertise of both university and agency researchers to address priority needs of federal, state, non-governmental, and tribal resource managers in meeting challenges associated with climate change. The SWCA hosts and works closely with the SW CSC and includes the University of Arizona (UA), University of California – Davis (UCD), University of California – Los Angeles (UCLA), Scripps Institution of Oceanography (SIO) at University of California – San Diego, University of Colorado (CU), and Desert Research Institute (DRI). The SWCA is joined by several partner institutions (Arizona State University (ASU), Northern Arizona University (NAU), University of California – Merced (UCM), University of Nevada, Las Vegas (UNLV), NASA Ames Research Center, and U.S. Institute for Environmental Conflict Resolution) that provide additional expertise and resources. Collectively, these institutions have a range of climate-related science capabilities, including:

Climate modeling and downscaling – The SWCA universities and their partners are among the top climate science universities in the Southwest. For example, UA, UCLA, Scripps, CU, and DRI are noted for their expertise in climate dynamics, global and regional climate modeling, ocean modeling, and climate-model downscaling.

Adapting to physical change – Several SWCA institutions have strength in physical sciences critical to the study of climate and adaptation to climate change. UA, Scripps, UCD, and CU are strong in physical hydrology and hydrologic modeling. Scripps, UCM, CU, and UCLA possess expertise in snow dynamics and Scripps, UCD, UCLA, and UA have significant coastal programs.

Adapting to ecosystem change – Understanding and adapting to changes in the great variety of southwestern ecosystems requires the diverse expertise and local knowledge contributed by our host and partner universities. UA, DRI, UCM, and Scripps collectively are authorities on disturbance science in the region, particularly with respect to wildfire and tree mortality. UA, UCD, and UCLA have strong programs focused on invasive species, whereas UCD and UCLA have expertise in the study of ecosystems and their changing distributions. UCD and UA have strong traditions in conservation biology and modeling individual species' responses to environmental change.

Adapting coupled human-environmental systems – SWCA universities have strong programs in environmental, social, and economic research (UCLA and UA), environmental law (UCLA, UA, UCD, and CU), and indigenous peoples' law (UCLA, UA, and CU). CU, UA, and NAU have strong academic programs concerned with Native Nations, and work closely with the American Indian tribes of the Southwest. UA also has many environmental programs focused on the US-Mexico border region, and both UA and CU have a strong tradition in the study and preservation of cultural heritage.

Adaptive management – UCD, CU, ASU, and NASA Ames are experienced in decision making under uncertainty. UA and UCD have multiple programs focused on adaptive management. Each of the SWCA universities has strong experience in environmental synthesis and stakeholder engagement.

Relation of the Southwest Climate Science Center to the Stakeholder Advisory Committee and Partners

The science planned, supported, and conducted by the SW CSC is informed by the needs of regional resource managers. The Stakeholder Advisory Committee (SAC), comprised of federal and non-federal senior-level executives from throughout the Southwest (Appendix 1), meets annually to share information and facilitate cooperation. Additional teleconference meetings are called when deemed necessary by the Chair. Committee members represent organizations whose missions variously involve research, management, regulation, and service, and are responsive to a variety of customers and constituencies. The California, Desert, Great Basin, and Southern Rockies LCCs are stakeholders with boundaries that overlap the SW CSC's focus area (fig. 1); all are or will be represented on the SAC (Appendix 1). The SAC also includes non-voting members from the scientific community to ensure diverse expertise and perspectives on priority science issues. Climate Science Center SACs are chaired by USGS Regional Directors; the Pacific Regional Director chairs the SW CSC. The SAC was established to facilitate (1) integration of the climate-relevant goals and science priorities of member organizations; (2) interorganizational, management-level guidance of the SW CSC climate research agenda; and (3) establishment of region-wide goals and science priorities for the SW CSC.

The SW CSC's protocols for proposal review avoid conflicts of interest, protect confidential information, and ensure that supported projects are of the highest scientific quality and address needs of resource managers. Each CSC will have a Science Implementation Panel or other interagency mechanism to oversee review of all proposed projects and to advise in addressing regional science priorities effectively and efficiently. Proposals and initiatives will be reviewed for relevance to SW CSC research priorities as well as regional to national priorities to identify opportunities for collaboration among CSCs. The review process will be coordinated by the SW CSC Director.

The 2012 SW CSC Strategic Science Agenda was developed in collaboration with the SAC, who provided input at their first meeting in December 2011 and commented on the draft. The annual planning process for the SW CSC will be coordinated with those of relevant LCCs. The SW CSC Director will communicate regularly with the SAC and LCC steering committees to coordinate activities and exchange information and updates.

Climatic Context of the Southwest

The SW CSC focal region includes California, Nevada, Utah, and Arizona (fig. 1). Nationally, CSC boundaries are fuzzy by design, and the importance of the Colorado River as a primary source of water for the Southwest dictates that the SW CSC's focal region include the upper reaches of the Colorado-Green River watershed in Colorado, Wyoming, and New Mexico. Within the SW CSC boundaries, the major physiographic provinces (Fenneman and Johnson, 1946) are the Intermontane Plateaus, the Pacific Mountain System, and parts of the Rocky Mountain System in the upper reaches of the Colorado River Basin. The topographic extremes within these provinces drive an immense range of variability in climate, ecosystems, and hydrologic systems; the Southwest region includes the highest and lowest points in the conterminous United States. Such varied topography strongly influences temperature, precipitation, evaporation, soils, and other variables that affect hydrologic and ecologic conditions. Precipitation in the area ranges from about 250 cm annually in parts of northern

California to less than 8 cm annually in Death Valley, with snowfall dominating in some areas and virtually absent in others. Surface-water hydrology includes large snowmelt-dominated rivers, such as the Colorado River, base-flow supplied perennial streams, and extensive ephemeral systems. The region's ecosystems reflect the diversity of topography and climate, and include deserts, woodlands, chaparral, forests, tundra, marine systems, and coastal wetlands. The Southwest also supports extensive human land uses, and includes some of the nation's most productive agricultural regions and largest urban areas.

Non-climate stresses on southwestern ecosystems and hydrologic systems increased dramatically through the 20th century as human populations expanded and human activities (for example, grazing, mining, irrigation, urbanization) intensified. Population in the region is projected to increase through the 21st century from an estimated 56 million in 2010 to 94 million in 2050 (Overpeck and others, 2012). Land-use and management practices will change as population increases. Similarly, anthropogenic water demand has increased as population has increased in many areas that are already water-limited. Natural climate variability combined with likely warming and drying imposes additional stresses on the region's natural resources.

The potential manifestations of climate change are wide-ranging and heterogeneous across the southwestern United States. Current research (MacDonald, 2010; Seager and Vecchi, 2010) and summary reports (Overpeck and others, 2012) indicate that changes in climate are underway and are projected to increase. The decade of 2001-2010 was the warmest since inception of record-keeping ca. 1901 (fig. 2). Additionally, tree-ring reconstructions of past climate indicate the period since 1950 has been warmer than any similar-length period in the past 600 years (Overpeck and others, 2012, Woodhouse and others, 2010). Hydrologic metrics have shifted as well. Analysis of 1958 – 2008 precipitation records show areas of increase and decrease in the Southwest. Portions of the Rockies and California experienced 10 to 20 percent increases, whereas desert areas of southern California and Arizona experienced decreases exceeding 40 percent (fig. 3). To put these decreases in perspective, work by Woodhouse and others (2010) indicate that the aridity observed over approximately the past decade may be the most severe since the 12th century. Changes in temperature, precipitation patterns, and dust have shifted the ratio of snow to rain (Knowles and others, 2006), resulted in earlier snow melt (Mote and others, 2006), and caused runoff to peak earlier in the spring (Stewart and others, 2005), while the amount of runoff has declined overall (fig. 4). Projections for the late 21st century show a statistically significant increase in number of days with maximum temperatures exceeding 32 °C across the region (fig. 5).

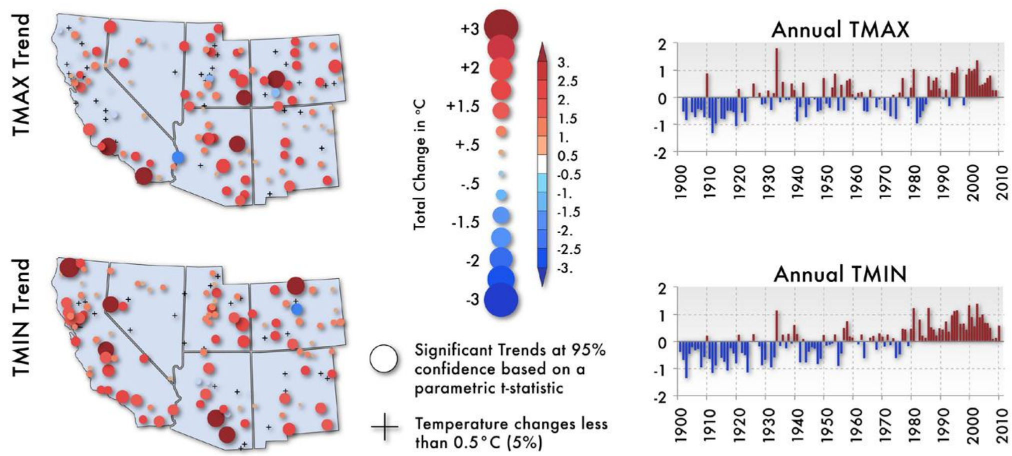

Figure 2. Temperature trends in the twentieth century. Units are change in °C/110 years. (from Overpeck and others, 2012). TMAX, maximum temperature. TMIN, minimum temperature.

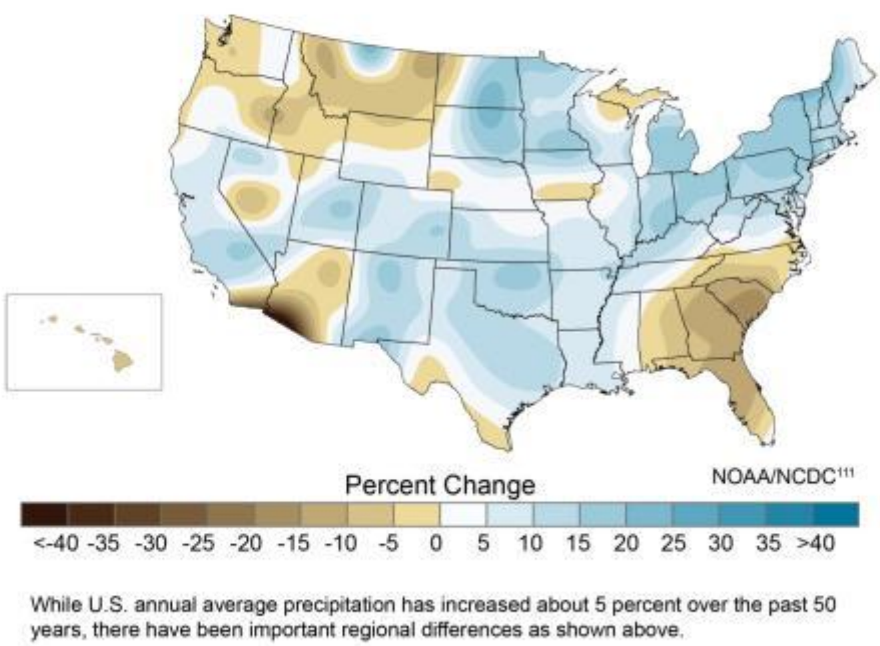

Figure 3. Observed changes in average annual precipitation, 1958-2008 (Karl and others, 2009)

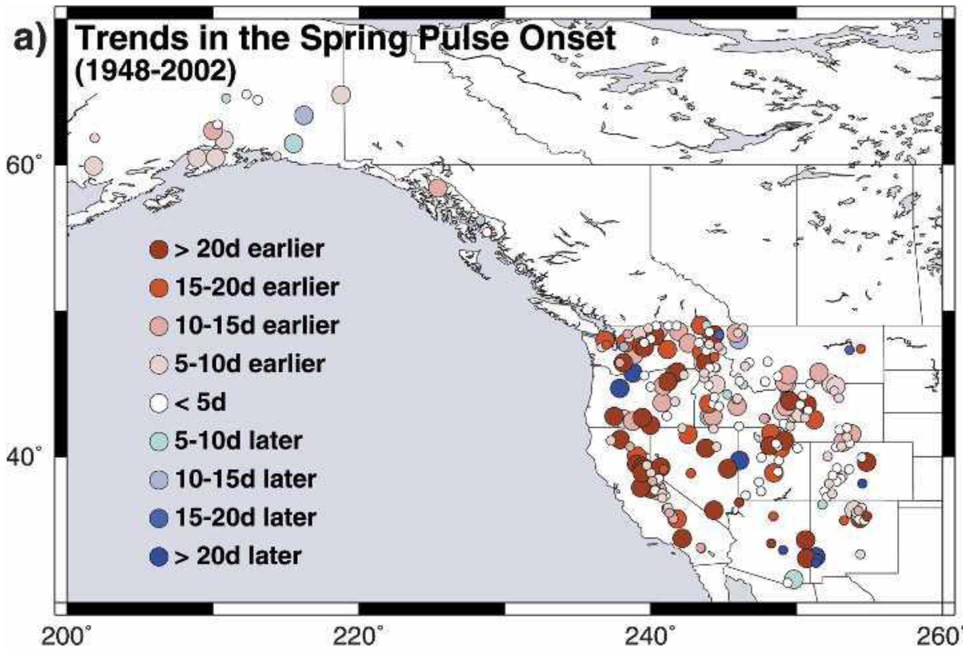

Figure 4. Trends in spring pulse onset – the beginning of snowmelt dominated streamflow – in days (d) for snowmelt-dominated streamflow gaging stations (from Stewart and others, 2005).

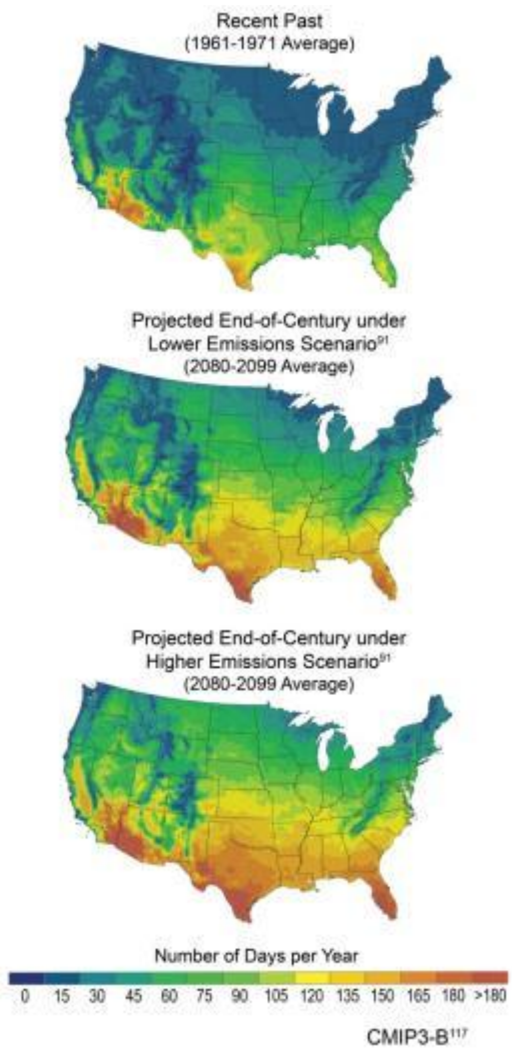

Figure 5. The average number of days per year when the maximum temperature exceeded 32 ˚C from 1961-1979 (top) and the projected number of days per year above 32 ˚C by the 2080s and 2090s for lower emissions (middle) and higher emissions (bottom). Much of the southern United States is projected to have more than twice as many days per year above 32 ˚C by the end of this century. (from Karl and others, 2009).

Projections for future climate and water resources in the area are largely consistent with trends observed in recent decades. Temperatures across the region are projected to increase, with higher maxima and minima and higher numbers of high-temperature days annually (fig. 5). Future water availability for people and ecosystems will change in less predictable ways. Hydrological model runs based on downscaled general circulation models project more-frequent drought (Cayan and others, 2010; Seager and Vecchi, 2010), but changes in precipitation amounts and intensity are likely to vary across the landscape. Changes in the seasonality of precipitation also are likely. Winter snowpack is likely to decline and trends toward earlier melting are likely to continue (Seager and Vecchi, 2010). Increased temperatures will have a direct effect on the water needs of plants by increasing transpiration and on water availability by increasing evaporation. While plant-water demand increases, soil moisture is likely to decrease in response to increases in temperature and changes in precipitation (Cayan and others, 2010). The combination of changes in temperature, precipitation and snowpack, soil moisture, and plant transpiration will tend to reduce runoff and base flow in streams. For the Colorado River system, research has suggested that total flow is likely to decline 10 to 30 percent over the next 30 to 50 years (Barnett and Pierce, 2008). Changes in human behaviors driven by climate may also affect water availability. For example, increased demand caused by increased temperatures combined with decreased surface-water availability may result in increased groundwater pumping, which in turn can affect stream base flow. Much remains unknown, however, about patterns of water availability in time and space as climate changes.

Ecological responses to climate variability and change are complex and diverse. Ecological and paleoecological studies show that southwestern ecosystems are sensitive to climate (Swetnam and Betancourt 1998, Swetnam and others, 1999), and ecological changes in response to changes in the Southwest’ s physical environment have been observed in recent decades. Tree mortality associated with increased heat and drought has increased rapidly in the past decade (Adams and others 2010). For example, thousands of square kilometers of piñ on pine woodland have undergone drought- and insect-driven mortality since 1999 (Breshears and others, 2005). Forest change and tree mortality has also increased in response to substantial increases in the number and size of wildfires in the western United States (Westerling and others, 2006). Since the mid-1980s, mean wildfire frequency and duration have increased, and wildfire seasons have become longer. A recent synthesis indicated that fire- and beetle-related tree mortality has affected more that 10 percent of the combined area of all southwestern woodlands and forests, and nearly 20 percent of the area of all southwestern forests, largely attributable to high temperatures and extreme drought (Williams and others, 2010). Current projections suggest that forest mortality within the next four decades will exceed that of the most severe droughts of the past thousand years (Williams and others, 2012). Changing climate is also affecting other ecosystems in the region. Evidence from the Chihuahuan Desert indicates that many species, including ants, horned lizards, rattlesnakes, and burrowing owls, are undergoing climate-driven changes in abundance (Brown and others, 1997). Increases in distribution and abundance of formerly rare species are attributed to recent changes in climate (Walther and others, 2002).

Many species are adjusting their elevational ranges upward (Moritz and others, 2008), but patterns are often complex, with some species shifting downward or staying in place (Crimmins and others, 2011; Tingley and others, 2012). Phenological patterns are shifting across the region; for example, flowering is starting earlier in the mountains of southern Arizona (Crimmins and others, 2009), although the rate and magnitude of change varies among species (Crimmins and others, 2010).

Coastal and marine systems in the Southwest are also affected by changes in climate and atmospheric chemistry. Rising sea levels resulting from global climate change will affect these systems in many ways, including inundation of low-lying areas, erosion of coastlines, and increased salinity in estuaries. These effects will compound when sea-level rise is superimposed on natural climate cycles, storms, and tides (National Research Council, 2012).

Human populations of the Southwest rely on the physical and biological resources of the region for water, food, and recreation. The climate-induced changes to the quality and availability of these resources described in the preceding paragraphs underscore the importance of effectively understanding the needs of resource managers and delivering the best science available to them. Landscapes in the Southwest are inextricably linked to the identity and economic well-being of individuals, communities, and the region as a whole. The collaborative government-academic CSC enterprise has been developed to connect the information needs of resource managers with the best scientific capacity available.

Vision

The vision for the Southwest Climate Science Center is to foster effective collaboration between scientists and resource managers in anticipating, monitoring, and adapting to climate variability and change in the Southwest, and attain national distinction in developing best practices for translational climate science.

Guiding Principles

The SW CSC and its partners face three challenges in fulfilling its ambitious vision. The first challenge is successful execution of the interdisciplinary research, scholarship, and engagement required to generate and deliver useful knowledge to stakeholders. The host institutions, USGS, and other agencies are widely recognized for their leadership in interdisciplinary research and problem-solving, and the SW CSC expects to draw heavily on this capacity.

The second challenge is the cultural contrast between the stakeholder communities and the research communities. These differences, which include language, professional reward systems, calendars and timelines, and perceptions of scientific capabilities and stakeholder needs, must be squarely acknowledged by CSC partners and personnel as a critical first step in collaboration and engagement.

The third challenge is that resources are finite, and the SW CSC cannot address all needs at all times. The SW CSC will strive to match stakeholder needs and research priorities and products.

To these ends, the SW CSC adopts the following set of guiding principles:

- ***Focus on management outcomes and solutions***
- ***Co-production of knowledge by stakeholders and scientists***
- ***Coordination of the different calendars of decision-making and research***
- ***Clear communication of scientific capacities and uncertainties***
- ***Utilization of experiential and local knowledge***
- ***Commitment to span professional and disciplinary boundaries***
- ***Development and application of metrics for gauging success***

Adherence to these principles requires trust, commitment, and engagement among all parties, including a willingness to transcend individual comfort zones. The SW CSC is committed to building communities of practice that integrate scientific knowledge with management concerns.

Goals of the Southwest Climate Science Center

Leadership goal: Match the information needs of stakeholder communities with the scientific capabilities of research communities

An essential role of the SW CSC is to provide leadership in bridging the fundamental information needs of resource managers and policy makers with the scientific and technical capabilities of the SWCA and USGS. The SW CSC will provide leadership in four critical ways. First, the SW CSC Director will enlarge and accelerate an ongoing dialogue with the region's stakeholders to identify their information needs and inform them of scientific capabilities and uncertainties. This dialogue will include a large array of stakeholders from the SAC, LCCs, and other entities, and scientists from the SWCA and other institutions. Second, the Director will work closely with CSC scientists and experts at the SWCA and affiliate institutions to identify the scientific knowledge required to address the stakeholder information needs. Opportunities will be provided for stakeholders to engage directly with scientists addressing their needs. Third, in coordination with the key partners, the Director will develop annual tactical objectives to address stakeholder needs. These tactical objectives will be described in the annual science workplan. Fourth, the Director will lead an ongoing effort to develop, implement, and evaluate best practices for collaborative co-production of knowledge by scientists and resource managers. The SW CSC Director will prioritize building relationships with resource managers in the region and developing effective strategies for communicating science to maximize the practical yield of the work supported.

Research goal: Foster development of interdisciplinary science to support resource management

The SW CSC will support a diverse research portfolio ranging from broadly conceived interdisciplinary campaigns to focused disciplinary projects and from long-term strategic efforts to short-term tactical solutions. The portfolio will be developed in coordination with the SAC, LCCs and other stakeholders, agency and other scientists, and the NCCWSC and other CSCs. The SW CSC will encourage development of interdisciplinary research teams to address stakeholder needs and scientific challenges. A key element of research supported by the SW CSC will be clear statement and, where possible, quantification, of uncertainties relevant to resource management. Research supported by the SW CSC will support management of resources by DOI, including (a) animal and plant populations, (b) terrestrial vegetation, including wildlife habitat, (c) freshwater resources, (d) cultural resources, and (e) coastal and marine ecosystems and resources. The SW CSC will also support research to address ecological and social processes that may amplify or mediate effects of climate, including wildfires and other severe disturbances, connectivity of land-use and land-cover types, recruitment dynamics, and non-native invasive species. The SW CSC expects to contribute substantively to design, implementation, and evaluation of climate-adaptation strategies by DOI, other federal agencies, American Indian tribes, state and civic governments, and other entities in the region.

Synthesis goal: Make relevant scientific and management information available to stakeholders and researchers.

The SW CSC will provide research products and syntheses for stakeholders in a variety of forms, including reports, maps, databases, summaries, reviews, and other publications. Publications may include USGS-series reports and papers published in professional journals and books. All such products will be made available on the SW CSC web site. The SW CSC will also disseminate summaries and syntheses of stakeholder needs and interests aimed at the research communities. It will act as an information hub to collect and make available products from sources outside the SW CSC that may be of interest to its partners. All datasets and syntheses supported by the SW CSC will be required to conform with the DOI Climate Data System Architecture and made available to interested parties. Although the SW CSC does not expect to directly collect and archive long-term data, it will leverage the expertise of staff and the host institutions to assist land and water management organizations, including the LCCs, in structuring new and ongoing monitoring programs. Additionally, the SW CSC will link data users to relevant datasets.

Critical Information Needs

The SW CSC's Stakeholder Advisory Committee and other stakeholders in the region have identified information they need to make resource-management decisions given climate change. *Supporting science*, defined as the science required to address such needs (Brown and Wilby, 2012), might be developed from direct application or interpretation of existing data, or might require new data or analyses. Identification of supporting science is effectively a gap analysis performed during preparation of this Strategic Science Agenda. The research themes described in the following section define, in broad terms, the science that will be pursued by the SW CSC over the next 3 to 5 years.

The science sponsored each year will be guided by the research themes and defined in annual science workplans. Collectively though time, the individual investigations sponsored by the SW CSC will develop the supporting science to address the stakeholders' information needs.

The critical information needs for the Southwest identified in coordination with the members of the SAC are:

Science Needs

1. Climate models appropriate for the spatial and temporal scales at which resource management decisions are made.
2. Effective links between groundwater/surface-water models and ecosystem models and metrics.
3. Links among climate models and hydrologic and ecosystem models.
4. Projected nature and impacts of extreme climate events (for example, storms and floods), including their frequency, duration, and spatial extent.
5. Projected effects of sea-level rise and ocean acidification on ecosystems and physical systems.
6. Knowledge about ecosystem and species resilience that will contribute to the development of effective restoration or adaptation strategies.
7. Monitoring strategies to collect interdisciplinary baseline data.
8. Strategies to improve communication with stakeholders about climate-change risks, consequences, uncertainties, and the state of the science.

Perceptions of critical information needs among stakeholders, scientists, and the SW CSC are likely to evolve in the coming years as dialogues continue. Such evolution is the essence of knowledge co-production (Lemos and Morehouse, 2005), and implementation of the Science Agenda, including the annual science workplans, will be an iterative process as all parties come to understand each other better. The general concerns and topics identified by stakeholders are not likely to change, although additions are likely as new issues and threats emerge. The Science Agenda has been designed to build on the SW CSC's dialogues with stakeholders, and to incorporate capacity for refining information needs and adapting to evolving needs and circumstances.

Research Themes

The following themes encompass both basic and user-driven research that will produce the knowledge and tools needed to address the information needs summarized above. The relation of themes to the needs they address is illustrated in fig. 6. The themes will evolve, but are sufficiently general to meet diverse information needs over the next 3 to 5 years. The Science Needs refer to those identified in the preceding section.

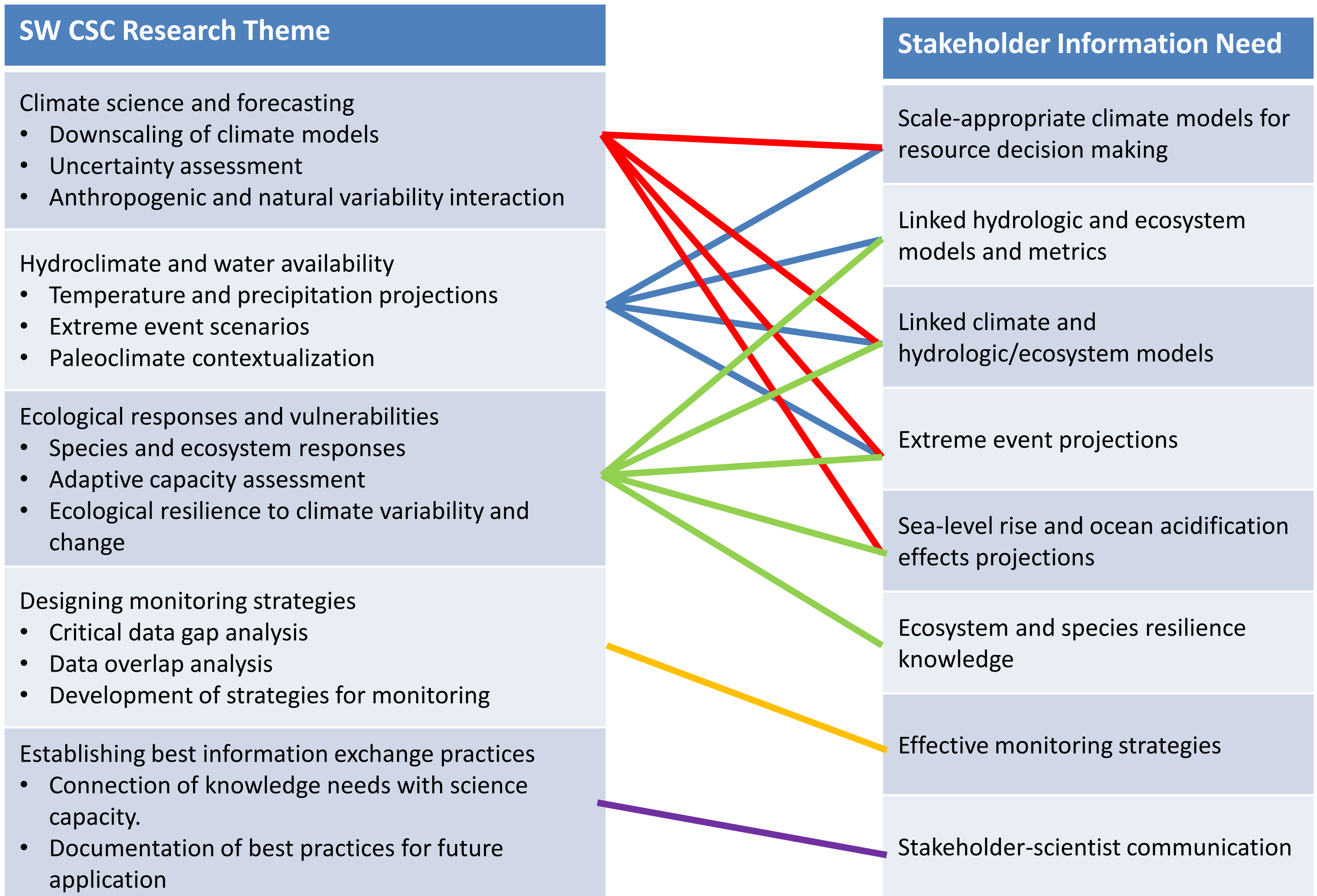

Figure 6. Relation between Southwest Climate Science Center (SW CSC) research themes and stakeholder information needs.

1. Climate Science and Forecasting (Science Needs 1,3,4,5). The SW CSC will continue to develop knowledge of climate change and variability in the context of resource management. Decision makers need information that allows them to anticipate and plan for climate change and variability across a range of time periods, from the coming months to the next century. Downscaled climate projections may be useful, but must be accompanied by realistic assessments of uncertainty, and will be most useful if managers and scientists reach mutual understanding of the nature and intended applications of the downscaled estimates. Long-term climate change will interact with higher-frequency variability in the ocean-atmosphere system (for example, El Niñ o-Southern Oscillation variation), which will leave distinct ecological signatures via mortality, disturbance, and recruitment. Similarly, projections and scenarios of climate extremes will inform resource management and adaptation. Understanding of how sea-level rise might interact with coastal upwelling and climate can be of considerable value to management of fisheries and other coastal resources. 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.

2. Hydroclimate and Water Availability (Science Needs 1,2,3,4). Hydroclimate is affected by both precipitation and temperature, and exerts control over water supply to rivers, lakes, estuaries and other 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 (for example, increasing temperature and earlier snowmelt) not only alter habitat for terrestrial and aquatic animals, but also pose threats (for example, wildfire, flooding) to human habitations near the urban-wildland border, agricultural activities, and human livelihoods. Subtle interactions can have large effects, often in distant regions (for example, acceleration of mountain snowmelt by dust deposition from devegetated basins). Suites of plausible future scenarios can be generated from integration of the newest generation of climate projections with state-of-the-art hydroclimatic, hydrological, and land-surface models (including vegetation models). Remote-sensing methods and data can play roles in parameterizing and testing such models. The rich historical and paleoenvironmental records from the region can also inform and expand the array of plausible future scenarios. Scientific knowledge can be incorporated into scenario planning, structured decision models, and other approaches to inform and engage stakeholders, who may require a range of information, from vulnerability and risk assessments to crisis-management preparation.

3. Ecological Responses and Vulnerabilities (Science Needs 2,3,4,5,6). Climate change and 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, will be a major focus of the SW CSC in the next few years. Some of the existing modeling and forecasting tools are more robust than others. Assessment of their potential accuracy and extent of uncertainty should precede their broader application or additional investment in increasing their precision. Emerging or underutilized approaches should be explored, including land-surface and ecosystem models, integrated assessment of species' adaptive capacity and climate sensitivity, and exploitation of geohistorical records. Other critical challenges include identifying and leveraging natural adaptive capacity, maximizing ecological resilience to climate change, and determining when and what kinds of interventions are necessary to achieve these goals. Development, assessment, and implementation of complementary approaches that capitalize on advances in ecological understanding, computing power, and quantitative methods can also minimize potential regulatory impediments on land use and resource management.

4. Designing Monitoring Strategies **(Science Need 7).** Data from monitoring networks are a resource for the SW CSC, LCCs, and other resource-management partners; scientific research, management decisions, and the evaluation of management outcomes all depend on data collected at the appropriate scale and frequency. Although the SW CSC recognizes the value of monitoring networks, it does not have the infrastructure or resources to initiate or support major data-collection efforts. The SW CSC does, however, have the expertise to identify substantial gaps and unnecessary duplication in current monitoring efforts. Accordingly, the SW CSC will actively assist LCCs and other resource-management partners by helping to identify monitoring priorities and strategies for the region that build upon the current monitoring and assessment activities.

5. Establishing Best Practices **(Science Need 8).** Perhaps the most important challenge in climate adaptation is reconciling the information needs of stakeholders with the 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 cross-cutting theme for the SW CSC. Insights can be gained from a variety of sources, including social-science literature, experiences of other communities engaged in translational science (for example, medicine and psychology), and examination of both successful implementations and failures and shortfalls in past efforts to adapt to climate and other environmental changes. Resource-management decisions are made at a broad range of scales, from immediate decisions at the level of individual management units to spatially extensive, long-range regional and national planning. Careful development and deployment of diverse approaches to translational climate science, coordinated with formal assessment of outcomes that draws from social-science research, will help identify best practices in specific settings.

Data and Product Management Strategy

To provide the highest value for resource managers, the science products of the SW CSC must be unbiased, based on sound science, and readily accessible. These requirements will be met by (1) archiving of data and information developed by CSC-sponsored projects in readily available data-management structures, and (2) publishing results following robust peer review. Accordingly, research data and products of the SW CSC will be subject to the provisions of the " Climate Science Centers and the National Climate Change and Wildlife Science Center Data Sharing Policy." In general, when SW CSC-supported research delivers products, the major findings should be promptly submitted to peer-reviewed professional and scholarly journals, with authorship accurately reflecting contributions to the product. In cases where effective communication to resource managers requires a level of background and detail not readily facilitated by such publications, peer-reviewed agency reports will be published. Investigators will be required to archive publicly, within a reasonable time, the data, samples, genetic baseline data, physical collections, and other supporting materials created or gathered.

Southwest Climate Science Center Scientific Expertise and Capacity

The long-term staffing plan for the SW CSC aims to build capacity to meet major research challenges while minimizing redundancy with existing capacity within USGS Science Centers and the SW CSC host institutions. The skills needed by the SW CSC will be defined iteratively and adaptively as the science themes are advanced and as gaps in capability are identified. In essence, the staffing decisions made by the SW CSC will adapt to needs as they develop. Generally, we intend to recruit individuals with interdisciplinary training or experience in bridging science and resource management. The Stakeholder Advisory Committee will provide advice on needed expertise and potential pathways for acquiring personnel with requisite technical skills, and will identify existing capacities within DOI agencies in the region. SWCA and USGS scientists will provide complementary advice and perspectives. The CSC Director will identify capabilities and needs, taking into consideration the existing skill sets in other CSCs, the capabilities of the host institutions, and needs identified by the SAC.

Department of the Interior partner agencies have been invited to embed scientists in the CSCs. This invitation is being extended to other partners, including federal agencies (for example, USFS, NOAA), states, American Indian tribes, NGOs, and universities. The Desert LCC Science Coordinator will be hosted by the SW CSC starting in February 2013.

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Appendix A. Stakeholder Advisory Committee members (2011-2012)

Name	Organization
Mark Sogge	USGS Pacific Southwest Area
Ren Lohoefener	Fish and Wildlife Service - Pacific Southwest Region
Benjamin Tuggle	FWS - Southwest Region
Terry Fulp	Bureau of Reclamation Lower Colorado Regional Office
Dale Morris	Bureau of Indian Affairs Pacific Regional Office
David M. Graber	National Park Service - Pacific West Region
Tom Poganik	Bureau of Land Management California State Office
Chrissy Howell	Forest Service - Pacific Southwest Region (PSW)
Jane L. Hayes	Forest Service - PSW Research Station
Deborah Finch	Forest Service - Rocky Mountain Research Station
Francisco Werner	National Oceanic and Atmospheric Administration - Southwest Fisheries Science Center
Chris Stathos	Department of Defense - Navy Region Southwest
Julia Levin	California Natural Resources Agency
John Andrew	California Department of Water Resources
Amber Pairis	California Department of Fish and Game, Climate Science and Renewable Energy Branch
Jennifer Newmark	Nevada Department of Conservation and Natural Resources, Natural Heritage Program
Laura Richards	Nevada Department of Wildlife, Wildlife Diversity Division
vacant	Utah
Bob Broscheid	Arizona Game and Fish Department
Paula Britton	Habematolel Pomo of Upper Lake
LeRoy N. Shingoitewa	Hopi Tribe
Diana Craig	California LCC Steering Committee Chair (Forest Service)
Larry Voyles	Desert LCC Steering Committee Chair (Arizona Game and Fish Department)
Steve Guertin	Southern Rockies LCC Steering Committee Chair (Fish and Wildlife Service Mountain-Prairie Region)
Rick Kearney	Great Basin LCC Steering Commiteee Chair (Fish and Wildlife Service Pacific Southwest Region)