

Integrating Climate Science for Decision-Support, Mitigating Risk and Promoting Resilience

Climate Assessment for the Southwest (CLIMAS) Phase 3

Annual Report for May 1, 2009–April 30, 2010

Table of Contents

CLIMAS Team _____	1
Main Stakeholders and Partners _____	1
Areas of Focus _____	3
Research and Stakeholder Collaboration Highlights ____	3
Tools, Models, and Products _____	11
Links with Other NOAA Programs _____	12
Cross-RISA Collaborations _____	12
Media _____	13
Workshops _____	14
Presentations _____	15
Publications _____	18
Peer-Reviewed Publications _____	18
Non Peer-Reviewed Publications _____	19





CLIMAS Team

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Main Stakeholders and Partners

Agua de Hermosillo
 Agri-Business Council of Arizona
 American Farmland Trust
 Arivaca Watershed Education Taskforce
 AZ Chamber of Commerce
 AZ County & State Health Depts.
 AZ County-level Local Drought Impact Groups
 AZ Dept. of Environmental Quality
 AZ Dept. of Water Resources
 AZ Division of Emergency Management
 AZ Electric Power Cooperative
 AZ Game & Fish Dept.
 AZ Governor's Drought Task Force
 AZ Public Service Corporation
 AZ Research Institute for Solar Energy
 AZ State Lands Dept.
 Bureau of Indian Affairs
 Bureau of Land Management
 CA Dept. of Forestry and Natural Resources
 CA Dept. of Water Resources
 Canadian Forest Service
 Central Arizona Project
 Center for Biological Research
 Center for Desert and Ocean Research
 Centro de Investigación Científica de Educación Superior de Ensenada
 Centro de Investigaciones Biológicas del Noroeste
 City of Chandler, AZ
 City of Hermosillo (Sonora)
 City of Las Vegas, NV-Business Leaders
 City of Mesa, AZ
 City of Phoenix, AZ
 City of Puerta-Peñasco (Sonora)
 City of Tucson, AZ
 City of Scottsdale, AZ
 Dept. of Defense
 El Colegio de Sonora
 Colorado Basin River Forecast Center

Colorado Division of Wildlife
 Colorado Natural Heritage Program
 Colorado River Water Users Association
 Comisión Nacional del Agua
 Comisión Estatal del Agua-Sonora
 Cotton Incorporated
 Denver Water
 Ducks Unlimited
 East Valley Water Forum
 Eastern Area Coordination Center
 Environmental Protection Agency
 Forest Guardians
 Grand Canyon Trust
 Gunnison County Stockgrowers
 High Country Citizens Alliance
 Hopi Dept. of Natural Resources
 IBM Global Services
 Instituto Mexicano de Tecnología del Agua
 Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias
 Instituto Municipal de Investigación y Planeación
 Intergovernmental Panel on Climate Change
 Intertribal Council of Arizona
 Jemez Pueblo, NM
 Kinship Conservation Fellows
 Los Alamos Natl. Laboratory
 Mexico Civil Protection/Disaster Relief Offices
 Mountain Studies Institute
 Multiagency Task Force of the Arizona Flood Warning System
 Native American Fish & Wildlife Society
 Natl. Association of State Foresters
 Natl. Interagency Coordination Center
 Natl. Interagency Fire Center-Predictive Services
 Natl. Judicial Law College
 Natl. Park Service
 Natl. Weather Service
 Navajo Nation

New Mexico Dept. of Forestry
 New Mexico Dept. of Game and Fish
 Nogales, AZ Water Utility
 Nogales, Sonora neighborhood leaders and official neighborhood associations
 Organismo Operador Municipal de Agua Potable Alcantarillado Saneamiento
 Pima County Flood Control
 Salt River Project
 Santa Clara Pueblo
 Science Foundation Arizona
 Seattle Public Utilities
 Servicio Meteorológico Nacional
 Sky Island Alliance
 Sonoran Institute
 Southern Nevada Water Authority
 Southwest Coordination Center
 The Audubon Society
 The Nature Conservancy
 Tohono O'odham Community College
 Trout Unlimited
 Tucson Water
 Upper Gunnison River Conservancy
 Universidad de Sonora
 U.S. Bureau of Reclamation
 U.S. Fish & Wildlife Service
 U.S. Geological Survey
 U.S. Northern Command
 USDA-Forest Service
 USDA-Natural Resources Conservation Service
 Utah Dept. of Water Resources
 Utah Division of Water Quality
 Washington Dept. of Natural Resources
 Water Utility Climate Alliance
 Western Governors' Association
 Western Resource Advocates
 Wild Utah Project
 Wildlife Conservation Society

CLIMAS projects are organized into six major areas of focus. The CLIMAS team works across a wide variety of integrated research themes, with any given project touching on at least two (and often many more) of these themes. For the purpose of this report, projects are highlighted within six of these areas of focus:

Areas of Focus

**Adaptation & Vulnerability | Climate Science | Communicating Science
Decision Support | Drought | Economics & Livelihoods**

Research and Stakeholder Collaboration Highlights

Adaptation & Vulnerability

Climate Change Projections and Scenarios for the Southwest

CLIMAS Investigators: H. Hartmann, G. Garfin, J. Overpeck, C. Woodhouse, K. Hirschboeck

Partners: Western Water Assessment, California Nevada Applications Program, Carpe Diem, Climate Impacts Group, National Park Service, NOAA Earth Systems Research Laboratory, Colorado Basin River Forecast Center, The Nature Conservancy, City of Phoenix Water Services Department, Bureau of Reclamation, Salt River Project, Central Arizona Project, Arizona Department of Water Resources, USDA Forest Service, Northern Arizona University, University of Washington, Wildlife Conservation Society, Arizona State University, Sustainability of semi-Arid Hydrology and Riparian Areas (SAHRA)

Abstract: This project represents a whole suite of activities conducted by members of the CLIMAS team. Through engagement with a variety of agencies and stakeholders, the investigators are developing methods, resources, and tools for considering climate change and non-stationarity in their planning. Through this project and leveraged activities, the research team is: (1) developing and applying scenario planning to address uncertainty of climate change and other stressors; (2) linking scenario planning and other decision-support processes; (3) evaluating needs and approaches for system-wide climate literacy training of National Park staff; (4) understanding the needs and capacities of the water resources sector related to climate change and non-stationarity; (5) evaluating methods for combining paleoclimatological information with historical observations and climate change projections into time series for use in planning; and (6) addressing the communication of uncertainty of projections of Colorado River flows under climate change and incorporation of those projections into planning.

Methods: These projects use workshops, dialogue, and experimental adaptation planning frameworks to elicit stakeholder needs and concerns. Climate change projections employ a combination of using statistical and dynamical downscaling approaches. Climate scenarios are derived from the projections using expert judgment.

Results: Preliminary findings show: (a) climate change projections and research alone are not enough to motivate change, because the peer-reviewed literature requires interpretation and decision makers lack the time to keep up with the sheer volume of publications; (b) a combination of estimates of future climate/environment states and discussion support to explore multiple future scenarios and research nuances is needed to move beyond “uncertainty paralysis”; (c) increased credibility is derived from active participation of the researchers involved in the primary research endeavors, and not just climate science translators; (d) leading-edge, early adopter stakeholders have embraced uncertainty as a platform for discussion and exploration of future climate change scenarios, research needs, monitoring needs, and communication with their publics.

Leveraged Funding Sources: The Nature Conservancy, City of Phoenix Water Services Department, Bureau of Reclamation, Salt River Project, Central Arizona Project

Reconciling Projections of Future Colorado River Streamflow

CLIMAS Investigators: H. Hartmann, K. Morino, J. Overpeck

Partners: Climate Impacts Group, California Nevada Applications Project, Western Water Assessment, Bureau of Reclamation, Colorado Basin River Forecast Center, NOAA Earth Systems Research Laboratory

Abstract: In support of the decision-making process, this research team is developing a framework that will provide multiple approaches for evaluating project results. Specifically, the team is outlining the application of decision analysis techniques to climate projections on the Colorado River. The projections generated by this project will ultimately be most useful to managers who need to know about the impacts of future streamflow variability on system resources. To this end, the team has been modifying the Bureau of Reclamation’s long-term planning and policy model, the Colorado River Simulation System (CRSS), in preparation for input of streamflow projection data. The team is finalizing an interview protocol to evaluate how project findings are informing policy and decision making in the basin.



Photo credit: National Park Service

Adaptation and Resilience to Climate Change, Drought, and Water Demand in the Urbanizing Southwestern United States and Northern Mexico

CLIMAS Investigators: M. Wilder, G. Garfin, G. Frisvold, J. Slack

Partners: National Center for Atmospheric Research, El Colegio de Sonora, Universidad de Sonora, NOAA Sectoral Applications Research Program, NOAA Earth Systems Research Laboratory

Other collaborators: R. Diaz, University of Arizona

Abstract: This project seeks to better understand (1) how water managers and civil and emergency-preparedness planners can use climate science and information to improve long-range and “adaptive” decision making, (2) how to regionalize the efficient development and delivery of relevant and usable climate outlook products and services, and (3) how to increase the resilience of urban border communities to climatic and water-resource uncertainties by integrating climate science into planning processes. This project targets four highly urbanizing ‘hotspots’ within the region: Tucson, AZ; the “twin” border cities of Nogales, AZ, and Nogales, Sonora; Hermosillo, the capital of the state of Sonora; and the area surrounding the coastal resort town of Puerto Peñasco, Sonora.

Methods: Surveys, interviews, and workshops geared to elicit information about how water managers and disaster relief officials use climate information, what kinds of products they use, and how they are used in operational planning decisions.

Results: This project has developed the quarterly *Border Climate Summary*, which is currently in its seventh issue and has produced a new binational network of water managers (local, state, federal) and a multidisciplinary group of researchers from Arizona, Colorado, Sonora, and Baja California. In addition, focused assessments on adaptive capacity in the cities has yielded recommendations, including: (1) improved information flows, essential for policy and adaptive response to climate and water uncertainty; and (2) programmatic responses must be built on existing agencies’ mandates with careful consideration of how such initiatives will be institutionalized, including the need for new organizational forms.

Leveraged Funding Sources: NOAA Sectoral Applications Research Program; Inter-American Institute for Global Change Research Small Grants Program for the Human Dimensions

Adaptation to Climate Variability and Change: Markets, Policy, Technology, and Information

CLIMAS Investigators: G. Frisvold, B. Colby, P. Dhanireddy

Other collaborators: S. Deva, K. Emerick, and A. Murugesan, University of Arizona

Abstract: This project examines different mechanisms for adapting to climate variability and change that include (1) the use of water markets by agriculture and urban water utilities, (2) the use of weather and climate information by agricultural producers, particularly for water management decisions, (3) the adoption of improved irrigation technologies, and (4) agricultural and other policy responses. This project includes statistical analysis of factors explaining differences in information use across farmers and ranchers and barriers to investing in water conservation.

Methods: Micro-economic models are used to develop and clarify hypotheses concerning farmer and rancher demand for climate, weather, and water management data and information. The project uses univariate and multivariate techniques to examine how climate, economic, and agronomic variables affect farm-level investments in improved irrigation technologies. The project develops game-theory models to examine how rural-urban water transfers can reallocate water regionally and to aid negotiations between the U.S. and Mexico in transboundary water management.

Results: The use of weather data by producers varies significantly by commodity group, degree of agricultural diversification, reliance on non-farm income, land ownership patterns, and attitudes towards risk management programs. Also, smaller scale farm operations are less likely to use irrigation management information, investigate irrigation system improvements, use scientific irrigation scheduling, or participate in government conservation program participation.

Integrating Climate Science for Decision Support, Mitigating Risk and Promoting Resilience

CLIMAS Investigators: B. Colby, G. Frisvold, H. Hartmann, C. Woodhouse, B. Chandra

Other collaborators: M. Mealy and M. O'Donnell, University of Arizona

Partners: Western Water Assessment, Bureau of Reclamation, Central Arizona Project, Salt River Project, AZ Electric Power Cooperative

Abstract: This project examines potential climate change and variability adaptation strategies in the water and energy sectors in the Southwest. Researchers are investigating how climate influences the market price of water and are developing a menu of supply reliability tools and guidelines for using these tools to enhance water supply reliability. Researchers are also developing improved methods for predicting and adapting to climate impacts to the generation of electricity.

Leveraged Funding Sources: NOAA Sectoral Applications Research Program, University of Arizona Office of Arid Lands Studies, Bureau of Reclamation



Climate-related vulnerability in a Nogales, Sonora colonia. After heavy rains, unpaved roads in this neighborhood become rutted and uneven.

Photo credit: M. Wilder

Patterns and Causes of Southwest Drought Variability

CLIMAS Investigators: J. Overpeck, C. Woodhouse, J. Conroy, C. Routson, J. Weiss

Other Collaborators: C. Castro and J. Cole, University of Arizona; M. Steinitz-Kannan, University of Kentucky; M. Bush, Florida Institute of Technology

Abstract: Droughts are one of the major concerns for the future of the Southwest, and yet the causes of drought in the region remain only partly understood. The situation is particularly acute when it comes to the decades-long “megadroughts” observed in the paleoclimatic record of the Southwest, and in the growing awareness that global warming is making droughts of the Southwest more acute. The goal of this project is to shed new light on the observations of current and past drought, as well as the causes and impacts of these droughts, including the role of ENSO versus Atlantic sea surface temperatures in modulating drought, the exact nature of medieval megadroughts in the Four Corners, the ecological impacts of drought, the evaluation of how well climate models simulate drought, and strategies for overcoming climate model deficiencies in assessing future drought.

Methods: Methods include analysis of paleoclimatic reconstructions, climate modeling and geospatial analysis.

Results: The primary findings to date include (1) Atlantic sea surface temperatures (SSTs) are as important to Southwest drought variability as those of the equatorial Pacific (e.g., ENSO); (2) the on-going drought of the Southwest has had unprecedented impacts primarily because of temperature increases and greater drought in the pre-monsoon season; and (3) atmospheric desert dust entrainment in the atmosphere in the Southwest is currently much above pre-European settlement levels.

Leveraged Funding Sources: NOAA Climate Change Data and Detection (C2D2), National Science Foundation, Department of Defense

Paleo-Southwest Monsoon Dynamics

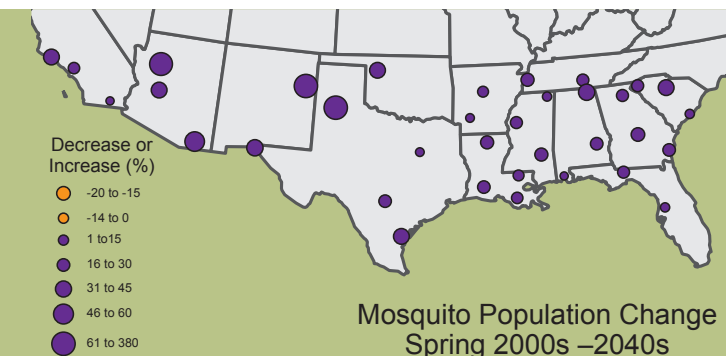
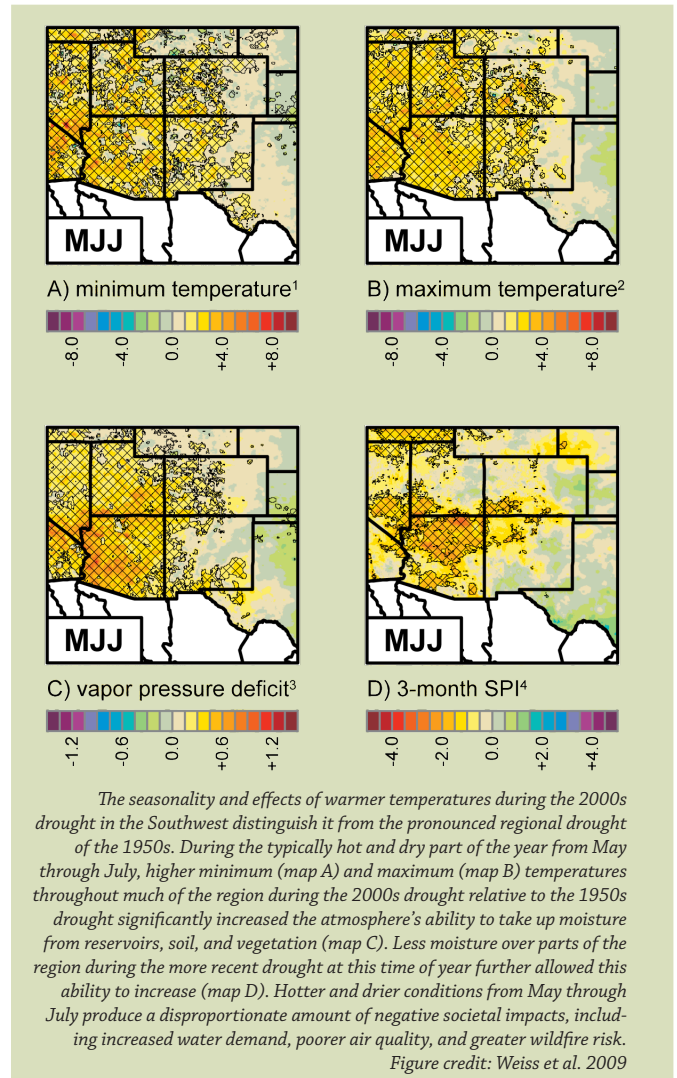
CLIMAS Investigators: J. Overpeck

Other Collaborators: J. Cole and S. Truebe, University of Arizona

Abstract: Little is known about the decade- to millennia-scale variations in the North American Monsoon and the response of this variability to changes in climate forcing. To help remedy this situation, the researchers are developing paleo-monsoon records using lake sediment and cave speleothems from sites in the southwestern United States and northern Mexico. This project examines the degree to which monsoon variations contributed to past climate extremes, including drought. Comparison between monsoon reconstructions and climate model results will help test hypothesized relationships between monsoon variability and sea surface temperature and other forcings.

Methods: Standard paleoclimatic methods for the study of lake sediment and speleothems. Dating via Pb-210, C-14, bomb nuclide and U-series. Stable isotopic, micro-xrf grainsize, microfossil, and other analysis.

Leveraged Funding Sources: Department of Defense, Science Foundation Arizona



Simulated Spring season changes in *Culex quinquefasciatus* population abundance (percent), showing the effective increase in population and extended overall mosquito season length under climate change projections. Figure credit: A. Comrie, C. Morin

Climate and Health

CLIMAS Investigators: A. Comrie, C. Morin, M. Butterworth

Partners: University of Arizona School of Geography, Department of Entomology, and Zuckerman College of Public Health

Abstract: Climate change and variability can strongly control the population dynamics of disease vectors such as mosquitoes, altering their location and seasonality and possibly increasing the risk of disease transmission to humans. This project develops and implements a climate-based Dynamic Mosquito Simulation Model to understand and project climate effects on mosquito population dynamics, developing results that will help climate-health scientists and public health decision makers better understand and project the role of climate in actual disease cases.

Methods: The basic approach uses deterministic numerical modeling to simulate mosquito population dynamics as well as the pathogenic development and transmission components. For application to climate change impacts, a statistical “weather generator” was used to appropriately downscale general circulation climate model output.

Results: (1) Climate is an important controller of mosquito population dynamics, and its effects can be well-simulated for theoretical and applied studies. (2) In general, under a changing climate, mosquito seasons across the southern U.S. will be longer, extending from earlier in spring to later in the fall, with lower mid-summer abundance in some locations. (3) The details are spatially unique because of differing land use patterns and the sensitivity of mosquitoes to complex interaction between temperature and precipitation.

Leveraged Funding Sources: National Science Foundation

Hydroclimatology and Paleohydrology for Decision Support

CLIMAS Investigators: K. Hirschboeck, H. Hartmann, C. Woodhouse, G. Garfin, A. Coles, K. Sammler

Partners: Tucson NWS, Pima County Flood Control, U.S. Geological Survey, Environmental Protection Agency

Abstract: This project is exploring innovative ways to address risk and resilience related to hydroclimatic extremes in both the upper and lower tails of streamflow probability distributions. The goal is to transfer the knowledge and record length that climate information and paleodata provide into useful tools for hydrologic decision making involving risk and resilience related to both floods and drought. A series of tools is being developed for integration into a map-based Web interface linked to a Flood Hydroclimatology Database for use by flood hazard and floodplain management stakeholders.

Communicating Science

The Southwest Climate Outlook (SWCO)

CLIMAS Investigators: Z. Guido, D. Ferguson, G. Garfin, M. Crimmins, G. Owen

Partners: University of Arizona Cooperative Extension, Arizona State Climate Office

Abstract: The *Southwest Climate Outlook* (SWCO) summarizes climate and weather information from disparate sources in nonscientific language, providing more than 1,600 people who receive it with timely and important climate-related information. The success of SWCO has resulted in the offshoot *Border Climate Summary*, which serves stakeholders on both sides of the U.S.-Mexico border. Since its inception in 2002, the SWCO has evolved into a significant “boundary object” for CLIMAS, providing a tool for two-way communication with stakeholders and a platform for responding to needs throughout the region. Examples of this in 2009—2010 include feature articles addressing stakeholder concerns (e.g., May 2009 article: “A warming world interspersed with cooling periods” and July 2009 article: “Who’s paying attention to the drought on the Colorado Plateau?”) and highlighting research important for regional stakeholders (e.g., February 2010 article: “Warmer means drier: comparing the 2000s drought to the 1950s drought” and April 2010 article: “The final gasp: Pinyon pines die faster during warmer droughts”).

Results: Highlights from this year include: continued evolution of SWCO presentation of forecast evaluation information; an improved email interface that provides easier access to SWCO summary information; production of 11 feature articles; an evolving effort to share feature articles for republication with partners including the Western Water Assessment and NOAA’s ClimateWatch.



A wet El Niño winter throughout the upper Salt and Gila river basins has resulted in well above-average streamflows for both rivers. This cover photo from the April 2010 Southwest Climate Outlook shows Saguaro Lake near capacity with water flowing over the spillway of the Stewart Mountain Dam.

Photo credit: J. Overpeck

Seasonal Climate Briefings

CLIMAS Investigators: G. Garfin, M. Crimmins



Monsoon rainclouds on the Colorado Plateau in Arizona.

Photo credit: Z. Guido

Partners: University of Arizona Cooperative Extension, National Weather Service, Servicio Meteorologico Nacional

Abstract: In 2009, CLIMAS co-hosted two climate Web briefings. The briefings this year bookended the monsoon season, with the May 21 briefing focused on monsoon forecasts and the October 26 briefing featuring a review of the 2009 monsoon season. These briefings are useful for sharing cutting-edge science (e.g., experimental monsoon forecasts) as well as providing researchers a forum for interacting directly with users of forecasting information. The briefings in 2009 attracted between 30 and 40 participants for each event. Participants included water managers and other resource managers, local media outlets, scientists, and interested citizens. Recordings of these, and all past briefings can be found at: <http://cals.arizona.edu/climate/ws/breeze.htm>.

Knowledge to Action: An Assessment of the Transfer of Climate Science to Decision Making

CLIMAS Investigators: D. Ferguson, C. Woodhouse, J. Rice

Partners: Western Water Assessment, Climate Impacts Group

Abstract: Many municipalities and water providers have become motivated to investigate the effects of climate variability and climate change on water resources. The primary objective of this project is to evaluate engagements of climate science and water management in three western cities—Denver, CO; Seattle, WA; and Tucson, AZ—and thereby contribute to a critical body of knowledge that will be a guide for other collaborative efforts and, more broadly, provide a possible template for other scientific outreach and coordination efforts, such as an effective national climate service.

Climate Science for Water Management in Tucson: An Occasional Lecture Series

CLIMAS Investigators: D. Ferguson, G. Garfin, K. Morino, C. Woodhouse, J. Overpeck

Partners: Tucson Water

Abstract: In 2009, scientists affiliated with CLIMAS began an occasional lecture series with Tucson Water staff about ongoing work related to climate and water management. The presentations are designed to share state-of-the-art research and solicit input from Tucson Water staff on how the research may be useful for their operations. The main goals of the project are to share cutting-edge science with interested Tucson Water staff and to foster discussions that help us understand what of research is useful to Tucson Water operations.

Methods: In-depth interviews are being conducted with key individuals in each region who have been involved in the production of useful climate information for water management (e.g. university-based researchers) and those that are working to use climate information in water planning efforts (e.g. water utility workers).

Leveraged Funding Sources: NOAA Sectoral Applications Research Program

Understanding and Communicating Climate Change in the Southwest

CLIMAS Investigators: J. Overpeck, D. Ferguson, G. Garfin, Z. Guido, H. Hartmann, C. Woodhouse, J. Weiss

Partners: Western Water Assessment, California Nevada Applications Program, NOAA Earth Systems Research Laboratory, University Corporation for Atmospheric Research, National Judicial Law College, University of Arizona College of Law

Abstract: The Southwest is one of the most sensitive regions of the U.S. to climate change and variability. It is essential to understand the full scope of climate variability and change in the Southwest and how to communicate in ways that enable effective decision making. The goals of this project are to (1) lead efforts to communicate about climate variability and change to decision and policy makers in, and relevant to, the Southwest, and (2) make climate knowledge useful for stakeholder understanding and decision making.

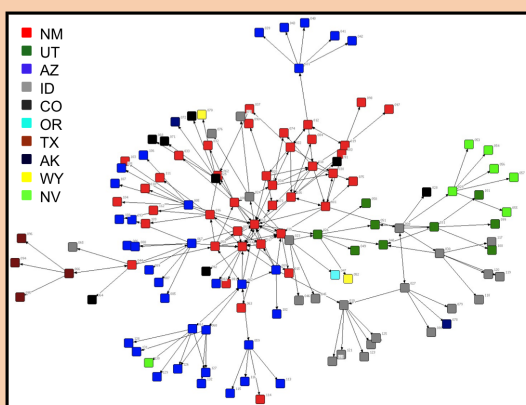
Leveraged Funding Sources: Arizona Department of Environmental Quality, University of Arizona Institute of the Environment

Climate Literacy and Training Assessment

CLIMAS Investigators: Z. Guido, D. Ferguson

Partners: Western Water Assessment

Abstract: Despite significant progress in improving climate literacy among a host of stakeholders, bringing climate change issues into focus in the context of decision making is an ongoing and growing challenge. Many resource managers do not know what information is available, where to find it, and how to interpret it. Much of the information available is targeted at well-represented user-groups such as water managers, leaving other others less informed. This project will conduct a broad assessment across diverse user groups in the Southwest to identify training needs specific to different groups and will identify appropriate processes to satisfy those needs.



This figure shows the SW Coordination Center's (SWCC) network of communication by state. Overall, there is integrated communication about fire management across the western states. Predictably, the network is located mostly in New Mexico and Arizona (the SWCC is located in Albuquerque, NM). The grey points represent people in Idaho, where the National Interagency Fire Center is located. Surprisingly, there are few representatives in Texas, even though part of the state is considered under the SW Coordination Center's jurisdiction.

Figure credit: J. McLeod

Evaluation of Fire Forecast Products to Enhance U.S. Drought Preparedness and Response

CLIMAS Investigators: G. Owen, T. Brown, D. Ferguson, J. McLeod

Other Collaborators: S. Trainor, Alaska Center for Climate Assessment and Policy; P. Duffy, Neptune and Company, Inc.

Partners: Alaska Center for Climate Assessment and Policy, California Nevada Applications Program

Abstract: This project assesses the impact that the National Seasonal Assessment Workshop (NSAW) seasonal and monthly fire outlooks have on decision makers who collaborate to manage wildfires in the western U.S. The project was inspired by increasing evidence that the following is not well documented: who uses the information in these products, for what purposes, or the economic benefits of using them. This project evaluates how these products are being used and also analyzes network patterns across regional and federal networks of fire management to see how information is communicated across agencies.

Methods: The project team used semi-structured interviews to collect data from people who work in fire management in the Southwest, Alaska, and at the federal level. The team used social network analysis to study the patterns of relations between actors and groups in the network.

Results: Preliminary findings include (1) fire managers use climate information much more heavily in the pre-season than during peak fire season, when they turn more to fire weather information, and (2) the NSAW product is generally useful, allowing managers a broad understanding of the kinds of decisions that may be made in the coming season.

Leveraged Funding Sources: NIDIS Coping with Drought

Putting Knowledge Into Action

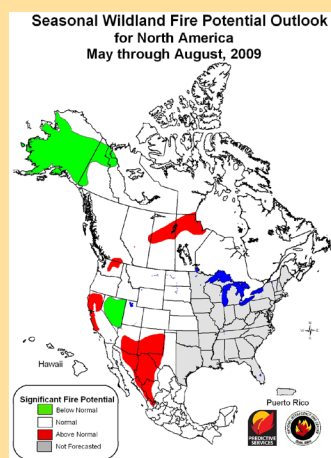
CLIMAS Investigators: Z. Guido, G. Garfin, D. Ferguson

Partners: U.S. Fish and Wildlife Service

Abstract: Climate change presents challenges for land and resource managers that will require new management priorities, strategies, and policies. The southwestern regions of the U.S. Fish and Wildlife Service (FWS) and the U.S. Geological Survey hosted a workshop to address management issues emerging from climate change. In 2009 CLIMAS synthesized information from the workshop into a published report that documents how some land managers in the West feel about climate change priorities and concerns, knowledge gaps, obstacles, and opportunities.

Leveraged Funding Sources: U.S. Fish and Wildlife Service

Decision Support



CLIMAS co-hosted the 7th National Seasonal Assessment Workshop and 4th North American Seasonal Assessment Workshop. NASAW follow up with colleagues from Servicio Meteorológico Nacional (SMN), in conjunction with NOAA's Office of Hydrologic Development, led to incorporation of substantial formal collaboration protocols between SMN and the RISAs in an updated Memorandum of Understanding between NOAA's OHD and CONAGUA, SMN's parent agency. Collaboration activities include (a) cooperation on the Border Climate Summary and other climate information products, (b) collaboration on the annual North American Seasonal Assessment Workshops, (c) cooperation on data transfer, and (d) development of experimental climate data and information products for northwestern Mexico.

Figure credit: Predictive Services, NIFC

National/North American Seasonal Assessment Workshops

CLIMAS Investigators: G. Garfin, T. Brown, G. Owen

Partners: Southeast Climate Consortium, Alaska Center for Climate and Policy, California Nevada Applications Project, Western Water Assessment, Southern Climate Impacts Planning Program, NOAA Earth Systems Research Laboratory, NOAA Climate Prediction Center, NWS Tucson, NWS Kansas City, Program for Climate Ecosystem and Fire Applications, Desert Research Institute, National Interagency Fire Center/National Interagency Coordination Center, Bureau of Land Management, USDA Forest Service

Abstract: The main goal of the National/North American Seasonal Assessment Workshops (NSAW) is to improve information available to fire management decision makers for allocation of firefighting resources at local, regional, and national scales. The NSAWs bring together fire meteorologists, fire behavior analysts,

fuel specialists, fire managers, climate forecasters, and climate researchers to produce pre-season fire potential outlooks, exchange ideas and information, and provide climate training to participants.

Results: Key areas of research include North American monsoon science and prediction; lightning forecasts; interactions between temperature and fire potential; forecasts of multi-day blocking high/ridging events; and economic estimates and/or forecasts of fire management resource needs associated with fire potential forecasts. Key areas of training include probability and statistics; use of teleconnections in seasonal climate-fire forecasting; and how climate change may affect seasonal prediction.

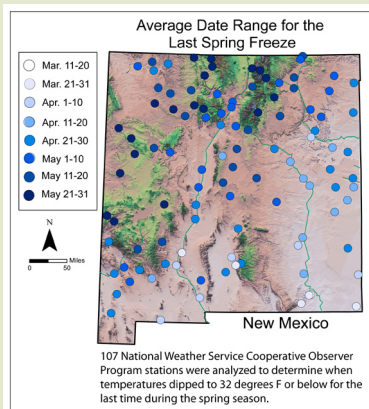
Leveraged Funding Sources: NOAA Climate Program Office, USDA Forest Service

Integrating Climate Science for Decision Support, Mitigating Risk, and Promoting Resilience

CLIMAS Investigators: R. St. Hilaire, G. Garfin, Z. Guido

Partners: Southeast Climate Consortium, New Mexico Climate Center, New Mexico State Agricultural Science Center at Farmington, USDA Jornada Experimental Range

Abstract: This project focused on the development of a Web-based, integrated decision-support tool to improve the use of climate information in management decisions. AgroClimate has been an ongoing project and contributions from this year include the development of an urban agricultural component and a freeze occurrence component. The urban focus allows users to estimate their monthly or yearly landscape water budget based on the landscaped area, areas of vegetation, or landscape plant composition. The freeze occurrence component allows users to visualize and access data for the historical dates of the first freeze in the fall (harvesting season) and last freeze in the spring (sowing season).



Understanding the historical timing of freezes in the spring and fall seasons can help agricultural stakeholders make informed decisions concerning planting and harvesting. This figure is part of a larger analysis performed on 107 National Weather Service Coop weather stations, and results will be posted after review in a Web decision-support tool: <http://nmclimate.nmsu.edu/climateriskdoc.html>. Preliminary results suggest numerous sites have displayed statistically significant changes in the timing of the first and last annual freezes, but that El Niño–Southern Oscillation events have no significant influence on the timing of freezes for most stations.

Figure credit: Z. Guido

Methods: For the urban water budget, the research team conducted a stratified sampling of zip codes, an image feature extraction using image classification and GIS software, an accuracy assessment of image classification using confusion matrices, and plant coefficient transfers.

Results: The freeze analysis documents that ENSO events do not significantly affect the timing of first fall and last spring freezes at the locations of most National Weather Service Coop weather stations. Also, there is no spatial coherence in the temporal trends in the timing of first fall or last spring freezes.

Developing Useful Science: Methods for Engaging Stakeholders and Evaluating Integrated Climate Tools

CLIMAS Investigators: G. Owen, Z. Guido, S. Laketa, L. Barros

Partners: Western Water Assessment, NWS Colorado Basin River Forecast Center

Abstract: This project is evaluating water supply forecasts in the Upper Colorado River Basin through the development of rigorous assessments of user needs. The goals of the project include (1) improving the CBRFC's water supply forecasts for various user groups; (2) expanding the user-base and enhance understanding of forecasts; and (3) understanding the role of uncertainty in interpreting and applying the forecast to risk and decision making. This research utilizes a variety of social science methods to demonstrate a process to help product developers identify, engage, and build relationships with diverse users, with the end goal of constructing more useful climate products.

Methods: This project uses educational workshops, focus groups, structured interviews, surveys, and decision games. With decision games, the team creates scenarios to observe participants engaged in simulated decision processes given a particular context. This method allows for systematic collection of qualitative and quantitative data on decision making.

Leveraged Funding Sources: NWS Colorado Basin River Forecast Center

TreeFlow: A Drought Planning Resource for Water Management in the Western U.S.

CLIMAS Investigators: C. Woodhouse, K. Hirschboeck, H. Hartmann, D. Griffin, R. Macaulay

Other Collaborators: J. Lukas, Western Water Assessment; S. Gray, Wyoming State Climatologist

Partners: Western Water Assessment, Climate Impacts Group

Abstract: Paleohydrologic information collected from tree rings have become valuable tools for drought planning and water resources management. The goal of this project is to expand that usefulness to a broader range of water providers and resource managers. This goal will be accomplished using a two-pronged approach that includes 1) an updated and comprehensive Web-based resource for data, applications, and analysis that addresses regional needs and interests and can be expanded to include additional regions of interest and reconstructions that are generated in the future, and 2) the development of a Web-based paleo toolkit to facilitate applications and use of streamflow reconstructions.

Leveraged Funding Sources: NIDIS Coping with Drought



Forecast Evaluation and Application Research

CLIMAS Investigators: H. Hartmann, B. Colby

Partners: NOAA Climate Services Division, NOAA Climate Prediction Center

Abstract: Stakeholders have identified significant barriers precluding more extensive and effective use of hydroclimatic forecasts, including lack of relevant and quantifiable forecast skill, misinterpretation of forecast products, and inability to place forecasts in historical context. Significant work is needed to develop specific forecast product formats that can be interpreted easily, correctly, and reliably without the need for special training. This project applies techniques for qualitatively and quantitatively assessing forecast performance with the intention of helping stakeholders appropriately align forecast use with measures of forecast skill. The project also examines the impacts of misinterpretation of forecast products.

Methods: Statistical forecast evaluation, workshops, interviews, participant discussion

Results: Different performance metrics show different aspects of forecast performance. NWS forecasters benefit from training about forecast interpretation, communication, and evaluation.

Leveraged Funding Sources: University of Arizona College of Agriculture and Life Sciences

Decision Support Tools: CLIDDSS, FET, and Others

CLIMAS Investigators: H. Hartmann, G. Garfin, C. Woodhouse, D. Hammond, E. Lay

Other collaborators: S. Srinivasin and C. Hansen, University of Arizona

Partners: Carolinas Integrated Sciences and Assessments, Southeast Climate Consortium, Pacific RISA, NOAA Climate Services Division, NOAA Climate Prediction Center, Northeast Regional Climate Center

Abstract: Barriers to the use of climate information can be met with innovative tools that offer users the ability to perform customized analyses. This project works to develop such tools, with a commitment to ongoing user engagement and adaptation of the tools. Rather than simply transfer the software, the research team is developing the capacities of RISAs, National Weather Service, and other partners to implement collaborative software development protocols and processes. The team also is working to link tools across concepts and applications through incorporation of Web services and the Climate Information Delivery and Decision Support System (CLIDDSS). Tools developed, maintained, or extended under this project include the Forecast Evaluation Tool, the Dynamic Drought Index Tool, AgroClimate, and the PaleoToolKit.

Methods: Computer engineering and programming, usability assessment, workshops, interviews

Drought

Evaluation of Arizona Drought Watch: The State's Drought Impacts Reporting System

CLIMAS Investigators: M. Crimmins, A. Meadow, D. Ferguson

Other Collaborators: S. Marsh, A. Olsson, T. Torrey, and A. Thwait, University of Arizona; S. Craig, Arizona Department of Water Resources

Abstract: Local drought impacts information is critical for monthly drought status reports, but the lack of local-level observations limits the state's ability to assess and mitigate drought effects. Arizona DroughtWatch (AZDW)—an online tool developed to increase and collect impact observation—has not generated sufficient interest by stakeholders. This project seeks to evaluate the development of AZDW to determine whether adequate stakeholder involvement was included in the process, and evaluate current use to determine whether revisions to the project could increase the use and usefulness of this decision-making tool.

Methods: Interviews, surveys of participants in the AZDW development process, current users, and agency representatives.

Leveraged Funding Sources: National Drought Mitigation Center

Arivaca Community Water Supply Drought Vulnerability Assessment

CLIMAS Investigators: Z. Guido, M. Crimmins

Partners: Arizona Water Resources Research Center

Abstract: Water supplies in aquifer systems that are recharged by current precipitation are vulnerable to drought because recharge rates decrease during dry conditions. Preliminary studies on the groundwater source for Arivaca, AZ, suggest that recharge comes from contemporary monsoon rains. This project investigates the relationship between climate variability and groundwater to assess the vulnerability of this community's principal water source to drought; it is also investigating options for sustainable water management.

Methods: Assemble available precipitation, streamflow, and groundwater level data within the study aquifer to evaluate potential climate-groundwater relationships. Relationships between datasets will be determined by calculating cross-correlation functions between each time series.

Leveraged Funding Sources: U.S. Geological Survey

Drought Monitoring and Planning in the Four Corners: Improving Drought Mitigation and Response with the Hopi Tribe Department of Natural Resources

CLIMAS Investigators: D. Ferguson, M. Crimmins, L. Barros

Partners: Hopi Department of Natural Resources, Bureau of Reclamation

Abstract: This project engages with Hopi colleagues to update the existing Hopi drought plan. This project seeks to (1) understand the major drought vulnerabilities confronting the Hopi; (2) understand the major adaptation strategies available to the Hopi; and (3) develop a plan that is more responsive and useful for responding to drought.

Economics & Livelihoods

Sectoral Impacts of Drought and Climate Change

CLIMAS Investigators: G. Frisvold, X. Ma

Partners: California State University San Bernardino, Arizona State University Department of Economics and the Morrison School of Agribusiness and Resource Management

Abstract: This project examines impacts of drought and climate change on climate sensitive sectors in the Southwest, focusing on agriculture and outdoor recreation and tourism. The U.S. Agricultural Resources Model, a 12-region, 32-commodity model of U.S. agriculture, is developed to examine effects of severe water shortages and large water price increases on agriculture in the Colorado and Upper



The Four Corners region of the Southwest has been experiencing prolonged drought since the late 1990s. La Niña conditions in winter 2009 contributed to a very dry winter that was ultimately compounded by a very weak summer monsoon season. This photo shows a withered cornfield on Hopi lands, summer 2009. Drought impacts on traditional agriculture are among the many concerns of tribal natural resource managers in the Four Corners as the drought persists.

Photo credit: C. Honyumptewa, Hopi DNR

Rio Grande basins. The project also combines regression and input-output models to assess how economic and environmental changes affect the local economies of gateway communities surrounding national parks in the Southwest.

Results: While agriculture in the region as a whole is resilient to water supply shocks, particular crops and regions are quite vulnerable. Crops grown in central Arizona—the region with the most junior water rights—are most vulnerable, while crops grown in western Arizona are little affected. Also, drought that affected the Southwest and led to large declines in reservoir elevations at Lakes Powell and Mead from 1998 levels caused a roughly \$42 million reduction in local sales, a \$15 million loss in local personal income, and a loss of more than 1,000 jobs.

Leveraged Funding Sources: The Marvin and June Morrison Chair in Agribusiness at



Handline sprinkler irrigation germinating crops in Yuma, AZ

Photo credits: J. Vanuga, USDA Natural Resources Conservation Service

Climate Change Mitigation Strategies and Policies

CLIMAS Investigators: G. Frisvold, L. Li, B. Subramaniam

Partners: American Farmland Trust, Arizona Research Institute for Solar Energy, University of Arizona Eller School of Management, Cotton Incorporated, New Mexico State University, Western Water Assessment

Abstract: This project includes three aspects of the economics of climate change mitigation (1) an economic evaluation of the effects of actual and proposed climate change mitigation policies, including cap-and-trade policies, renewable energy portfolio standards, and energy pricing policies; (2) a comparison of state energy and carbon emission intensity and climate mitigation policies, seeking to examine how state resource endowments affect policy development and resource use; (3) an examination of strategies to sequester carbon or reduce carbon emissions.

Methods: Econometric analysis was applied to examine state-level diffusion of technological and policy innovations. This included diffusion of conservation tillage practices (which sequester soil carbon), state adoption of greenhouse gas targets, and state adoption of renewable energy portfolio standards. Analysis has included techniques of event history analysis as well as econometric models of simultaneous diffusion of technologies.

Results: Proposed cap-and-trade legislation will have modest impacts on agricultural production in the short run because of special protections for energy intensive trade-exposed entities, which will substantially reduce increases in fertilizer costs. Contrary to popular belief, solar thermal electricity production would not place a significant burden on the Southwest's water or land resources. Research results suggest that if Arizona met its 2030 15 percent renewable electricity portfolio standard using combinations of photo voltaic and solar thermal generation, water requirements would be less than 0.25 percent of current use.

Leveraged Funding Sources: American Farmland Trust, Cotton Incorporated

Tools, Models, and Products

Arizona DroughtWatch

M. Crimmins

This tool is designed to collect qualitative reports of drought impacts across Arizona. This impact information is used in conjunction with meteorological and hydrological data to characterize drought conditions. (<http://azdroughtwatch.org>)

Border Climate Summary/Resumen del Clima de la Frontera

G. Garfin, M. Wilder, R. Macaulay

This bilingual communication tool provides regionally specific climate information to stakeholders in the Arizona-Sonora border region. The summary is sent out quarterly to a list of 1,500 people, which includes water managers, land managers, and disaster relief officials. (<http://climas.arizona.edu/forecasts/border/summary.html>)

Dynamic Mosquito Simulation Model (DyMSiM)

A. Comrie, M. Butterworth, C. Morin

Continued development of the climate driven DyMSiM to assess the effects that climate change and variability may have on two mosquito disease vectors. The model simulates mosquito population dynamics for *Culex quinquefasciatus* and it is currently being adapted for *Aedes aegypti*. The model code will be made publicly available in summer 2010.

Flood Hydroclimatology Tools

K. Hirschboeck

Tools that are being explored include (1) historical flood-hydroclimatology overviews for local watersheds; (2) time-sequence maps of gauged discharge and precipitation leading up to historical peak flow events for comparison with flood events evolving in real time; (3) long-term records of hydroclimatically separated flood types for statistical comparison with real time observations; (4) synoptic circulation scenarios and teleconnection links for different flood types and historical flood episodes for comparison with evolving

model forecasts; and (5) paleoflood-defined upper limits of expected flood peaks for each watershed, derived from the Arizona Paleoflood Databank.

Forecast Evaluation Tool

H. Hartmann, B. Colby, M. Mealy

The FET provides a variety of information about climate forecasts with interactive graphic tools, maps, and charts. It is intended to improve knowledge about forecast verification and about climate and water supply forecast skill in the Southwest. It is currently used by the National Weather Service and the Climate Prediction Center. (<http://fet.hwr.arizona.edu/ForecastEvaluationTool/>)

New Mexico Freeze Dates

Z. Guido, G. Garfin, R. St. Hilaire

This online Web tool estimates the first fall and last spring freeze dates each year. It is designed to help farmers plan their sowing and harvesting dates. The tool incorporates data from 107 National Weather Service COOP weather stations in New Mexico to determine the probability of freeze dates. (<http://nmclimate.nmsu.edu/freeze/>)

Southwest Climate Change Network

J. Overpeck, D. Ferguson, Z. Guido, G. Owen, G. Garfin, M. Crimmins

This Web site provides regionally focused information on climate change science, impacts, and solutions. It is designed as a platform to communicate with decision makers and policy makers in the Southwest about climate variability and change. (<http://www.southwest-climatechange.org>)

Southwest Climate Outlook

Z. Guido, G. Garfin, M. Crimmins, D. Ferguson, G. Owen, R. Macaulay

This monthly communication tool summarizes climate and weather information from disparate sources in nonscientific language. It provides more than 1,600 people with timely and important climate-related information. SWCO includes information on recent conditions, such as precipitation and temperature during the last 30 days; forecasts, such as El Niño-Southern Oscillation; forecast verification; and news. (<http://climas.arizona.edu/forecasts/swoutlook.html>)

TreeFlow

C. Woodhouse, H. Hartmann, K. Hirschboeck

Updated tree-ring streamflow reconstructions for decision support in the Lower Colorado and Rio Grande river basins. The tree-ring based hydroclimatic scenario products are designed for use as tools in drought management and planning across the West. Currently in development is a set of “Sequences of Droughts and Variability in the Gage Record” tools. These are aimed towards water resource professionals interested in evaluating gage records in the context of longer tree-ring reconstructions. (<http://treeflow.info/toolbox.html>)

Toolkit for Engaging Users in Climate Services

G. Owen, Z. Guido, D. Ferguson

This toolkit includes descriptions and examples of social science methods to evaluate climate service products. These include usability evaluations, pre- and post-workshop surveys, and decision-making scenario activities. Currently they are being used to evaluate the Colorado Basin River Forecast Center’s Water Resource Outlook.

Water Budget Calculator

R. St. Hilaire, G. Garfin, S. Al-Kofahi

This integrated decision-support tool is designed to improve drought management in urban landscapes in Albuquerque, NM. The Web tool allows users to estimate their monthly or yearly landscape water budgets based on inputs such as size of the landscaped area, plant composition, and the current ENSO signal. (<http://nmclimate.nmsu.edu/wb/index.html>)

Links with Other NOAA Programs

- Earth Systems Research Laboratory
- Sectoral Applications Research Program
- Climate Prediction Center
- Arizona & New Mexico State Climatologists
- Western Regional Climate Center
- NWS Colorado Basin River Forecast Center
- NWS WFOs in Tucson, Phoenix, Albuquerque, Kansas City
- CLIMAS currently works with all of the RISAs: Western Water Assessment (WWA), Climate Impacts Group (CIG), Southeast Climate Consortium (SECC), Alaska Center for Climate Assessment and Policy (ACCAP), Southern Climate Impacts Planning Program (SCIPP), California Applications Program (CAP), Carolinas Integrated Sciences and Assessments (CISA), Pacific RISA

Cross RISA Collaborations

Coping with Drought Cross RISA Projects

- TreeFlow: A Drought Planning Resource for Water Management in the Western U.S. (Western Water Assessment and Climate Impacts Group)
- Evaluation of Fire Forecast Products to Enhance U.S. Drought Preparedness and Response (Alaska Center for Climate Assessment and Policy and California Applications Program)
- Reconciling Projections of Future Colorado River Stream Flows (Western Water Assessment, California Nevada Applications Program, Climate Impacts Group)

Other Cross RISA Collaborations

- Integrating Climate Science for Decision Support, Mitigating Risk and Promoting Resilience (Western Water Assessment)
- Knowledge to Action: An Assessment of the Transfer of Climate Science to Decision Making (Western Water Assessment, Climate Impacts Group)
- Climate Change Mitigation Strategies and Policies (Western Water Assessment)
- Evaluation of Fire Forecast Products to Enhance U.S. Drought Preparedness and Response (Alaska Center for Climate and Policy, California Nevada Applications Project)
- Developing Useful Science: Methods for engaging stakeholders and evaluating integrated climate tools (Western Water Assessment)
- Climate Change Projections and Scenarios for the Southwest (Western Water Assessment)
- National/North American Seasonal Assessment Workshops (Southeast Climate Consortium, Alaska Center for Climate and Policy and California Nevada Applications Project, Western Water Assessment, Southern Climate Impacts Planning Program)
- Understanding and communicating climate change in the Southwest (Western Water Assessment and California Nevada Applications Project)
- Integrating Climate Science for Decision Support, Mitigating Risk and Promoting Resilience (Southeast Climate Consortium)
- Climate Literacy and Training Assessment (Western Water Assessment)

Media

The CLIMAS program and its members are constantly featured in local and national media, including newspapers, podcasts, and documentaries. The media often cites CLIMAS members for their expertise, their publications, and the results they generate from particular projects. The following examples highlight how and where CLIMAS receives media attention.

Expertise

Gregg Garfin:

- Climate Change Research Broadens to Meet New Challenges (*Science Magazine*, Nov. 2009)
- Cold and Stormy Weather on Way (*Tribune Regional News – Albuquerque*, Oct. 27, 2009)

Jonathan Overpeck:

- Southwest to suffer most from global warming (*USA Today*, Aug. 1, 2009)
- Report: Climate Change Evident: Rising temperatures, dwindling snowpacks shown in New Mexico (*America's Intelligence Wire*, Jun. 17, 2009)
- State in 'bull's-eye' for change (*Arizona Daily Star*, Jun. 17, 2009)
- Predicting the Crash: Tracking Tipping Points (*All Things Considered*, National Public Radio, Sept. 16, 2009)
- Climate Change and the Weather (*Focus Earth, Planet Green*, January 2010)

CLIMAS Projects & Publications

George Frisvold:

- Climate Change Laws Pose Challenges, Opportunities for Agriculture (*States News Service*, Apr. 26, 2010)

Gregg Garfin:

- Researchers to get award for Colorado River paper (*Associated Press*, Jul. 20, 2009)

Southwest Climate Outlook:

- The great monsoon washout of 2009 (*Arizona Daily Star*, Aug. 30, 2009)
- Wet's a good bet: Upgraded El Niño likely to bring Tucson a long spell of moisture (*Arizona Daily Star*, Dec. 4, 2009)
- Reporter Bill Buckmaster quotes SWCO forecasts each month on National Public Radio local news segments

Workshops

Workshop name	CLIMAS lead(s)	Dates	Location	Partners	Details
User-feedback on New Gridded Soil Moisture and Precipitation Data Products	Gigi Owen, Zack Guido	14 May 2009	Tucson, AZ	Colorado Basin River Forecast Center	Nine participants representing 3 federal government agencies, 2 NGOs, and 1 university
Variability and Climate Change on the West Coast of North America (Second Stakeholder Workshop for the SARP/IAI/CLIMAS project)	Margaret Wilder, Gregg Garfin	22 Jul 2009	Jiutepec, Morelos, Mexico	IMTA (Instituto Mexicano de Tecnologia del Agua), Udall Center for Studies in Public Policy, COLSON (Colegio de Sonora)	~ 50 participants, representing 5 federal agencies, 4 universities/research institutes, 1 municipal agency, 1 NGO; from Mexico; 1 federal agency, 5 universities/research institutes from U.S.
Planning for Climate Change Through an Integrative Approach to Water Planning, Climate Downscaling, and Robust Decision Making: Paleohydrology Workshop	Gregg Garfin, Connie Woodhouse	11 Sept 2009	Phoenix, AZ	Arizona Water Institute, Arizona State University, City of Phoenix, University of Arizona, U.S. Bureau of Reclamation	~ 40 participants, plus 10 via streaming video, representing 8 municipal water providers, 1 county agency, 2 state agencies, 1 tribal agency, 1 federal agency, 4 NGOs, 3 universities/research institutes.
Variability and Climate Change on the West Coast of North America (Third Stakeholder Workshop for the SARP/IAI/CLIMAS project)	Margaret Wilder, Gregg Garfin	2 Oct 2009	Puerto Peñasco, Sonora, Mexico	Udall Center for Studies in Public Policy, COLSON (Colegio de Sonora), Municipio de Puerto Peñasco, Instituto Superior Tecnológico de Puerto Peñasco, NOAA Earth Systems Research Lab, Western Water Assessment	~ 70 participants, representing 4 federal agencies, 6 universities/research institutes, 4 municipal agencies, several NGOs from Mexico; 1 federal agency, 4 universities/research institutes from the U.S.
Planning for Climate Change Through an Integrative Approach to Water Planning, Climate Downscaling, and Robust Decision Making: Uncertainty Workshop	Gregg Garfin	6 Nov 2009	Phoenix, AZ	Arizona Water Institute, Arizona State University, City of Phoenix, University of Arizona, U.S. Bureau of Reclamation, Central Arizona Project.	~ 40 participants, representing 6 municipal water providers, 2 state agencies, 1 tribal agency, 2 federal agencies, 2 NGOs, 4 universities/research institutes.
Western Watersheds and Climate Change: Water and Aquatic Systems Tools Workshop	Gigi Owen	17-19 Nov 2009	Boulder, CO	Colorado Basin River Forecast Center, Western Water Assessment	~ 30 participants representing western U.S. Forest Service offices.
Southwest Climate Change Initiative (SWCCI): Climate Change Adaptation Workshop for Natural Resource Managers in the Gunnison River Basin	Gregg Garfin	2-3 Dec 2009	Gunnison, CO	The Nature Conservancy, The Wildlife Conservation Society, University of Washington, USDA-Forest Service	~ 60 participants, representing 6 federal agencies, 3 state agencies, 6 NGOs, 5 universities/research institutes.
Overview of Arizona DroughtWatch	Michael Crimmins, Daniel Ferguson	3 Dec 2009	Kykotsmovi, AZ	Hopi Department of Natural Resources	~ 15 participants representing each program within the Hopi Department of Natural Resources.
Piloting the Streamflow Forecast Workshop	Gigi Owen	23 Mar 2010	Salt Lake City, UT	Colorado Basin River Forecast Center, Western Water Assessment	Twelve participants, representing 2 federal agencies
Planning for Climate Change Through an Integrative Approach to Water Planning, Climate Downscaling, and Robust Decision Making: Colorado River Climate Change Projections Workshop	Gregg Garfin	2 Apr 2010	Phoenix, AZ	Arizona Water Institute, Arizona State University, City of Phoenix, University of Arizona, U.S. Bureau of Reclamation, Central Arizona Project	~ 40 participants, representing 7 municipal water providers, 1 state agency, 1 federal agency, 1 NGOs, 7 universities/research institutes.
Southwest Climate Change Initiative (SWCCI): Climate Change Adaptation Workshop for Natural Resource Managers of the Four Forests Restoration Initiative Area	Gregg Garfin	7-8 April 2010	Flagstaff, AZ	The Nature Conservancy, The Wildlife Conservation Society, University of Washington, USDA-Forest Service	~ 45 participants, representing 4 federal agencies, 2 state agencies, 4 NGOs, 3 universities/research institutes.
Drought Preparedness for Tribes in the Four Corners Region	Daniel Ferguson, Michael Crimmins	8-9 Apr 2010	Flagstaff, AZ	National Drought Information System, the National Drought Mitigation Center, USGS, WWA	Approximately 40 participants representing 6 tribes in the region, 4 federal agencies, and 3 universities/research institutes.
2010 National/North American Seasonal Assessment Workshop	Gregg Garfin, Tim Brown	19-23 Apr 2010	Boulder, CO	National Interagency Fire Center Predictive Services, California Nevada Applications Program, Western Water Assessment, Rocky Mountain Coordination Center, Alaska Coordination Center	~ 45 participants, representing 6 federal agencies, 4 state agencies, 4 universities/research institutes, 2 international federal agencies.
The Streamflow Forecast Workshop: Using & Improving the Tools Available at the Colorado Basin River Forecast Center	Gigi Owen	23 Apr 2010	Grand Junction, CO	Colorado Basin River Forecast Center, Western Water Assessment	

May 2009

- Frisvold, G. May 2009. Arizona 2009 economic outlook for agriculture. Arizona Agribusiness Council Annual Meeting. Phoenix, AZ
- Garfin, G. May 2009. Climate change in the Southwest. Interfaith Power and Light (multi-faith climate change stewardship and action initiative) kick-off meeting. Tucson, AZ. (invited)
- Garfin, G. May 2009. Climate forecasts and forecast uncertainty. Abdus Salam International Center for Theoretical Physics, Trieste, Italy. (invited)
- Garfin, G. May 2009. Translational environmental research: Improving the usefulness and usability of research results. GEOTEACH II. Biosphere II, Oracle, AZ. (invited)
- Hartmann, H. May 2009. Observations, modeling, and research in support of public service. University of Arizona Climate Dynamics and Hydrometeorology Center (CDHC) Annual Retreat. Biosphere 2. Oracle, AZ.
- Overpeck, J.T. May 2009. Invited Speaker, U.S. Congress House and Senate Briefings on Adaption to Climate Change, Focus on Water. Washington, DC.
- Overpeck, J.T. May 2009. Invited to present testimony at field hearing on “The Effects of Water Quality Issues in the Lower Colorado River,” Subcommittee on Water and Power, U.S. House of Representatives. Tucson, AZ.
- Wilder, M. May 2009. Water and climate projects in the Arizona-Sonora region. Meeting of the Tucson chapter of Arizona Hydrological Society. Tucson, AZ.

June 2009

- Ferguson, D.B. June 2009. The challenges of monitoring drought and climate change on Indian lands in the Southwest. NIDIS Climate, drought and early warning on Western Native Lands workshop. Jackson, WY.
- Frisvold, G. June 2009. Demand for visits to southwestern national parks. Western Economics Association International Annual Meeting. Vancouver, BC.
- Garfin, G., C. Scott, M. Pasqualetti, J. Hoover, J. Guhathakurta. June 2009. Water and energy sustainability with rapid growth in the Arizona-Sonora Border Region. Arizona Water Institute Researcher-Managers Workshop. Tucson, AZ.
- Hirschboeck, K.K. June 2009. Addressing the hydroclimatology of extreme flow events in the Santa Cruz River Basin. EPA-USGS Workshop on Ecosystem Services Analysis of Climate Change and Urban Growth in the Upper Santa Cruz Watershed. Tucson, AZ.

July 2009

- Al-kofahi, S. July 2009. Establishing a decision-making tool to reduce drought vulnerability in residential urban landscapes. Annual Meeting of the American Society for Horticultural Science. St. Louis, MO.
- Colby, B. July 2009. Economic considerations in climate change adaptation. Kinship Conservation Fellows Annual Workshop. Bellingham, WA.
- Conroy, J.L., Overpeck, J.T., Cole, J.E., and M. Steinitz-Kannan. July 2009. Variable oceanic teleconnections to western North American drought over the last 1200 years. PAGES Young Scientist and Open Science Meetings. Corvallis, OR.
- Ferguson, D.B. July 2009. A global perspective on climate change in the Southwest. Native American Fish & Wildlife Society Southwest Region Annual Conference. Isleta Pueblo, NM. (invited)
- Garfin, G. July 2009. Projected climate change and impacts for the Southwest: The known, the uncertain, and the unknown. Southwest Endangered Species Act Team Meeting. Flagstaff, AZ, (invited) (Note: the Southwest Endangered Species Act Team consists of federal and state land and wildlife managers from Arizona and New Mexico).
- Overpeck, J.T. July 2009. Invited participant to IPCC Fifth Assessment Report Scoping Meeting. Venice, Italy.
- St. Hilaire, R. July 2009. Linking landscape types to water use in residential landscapes. Annual Meeting of the American Society for Horticultural Science. St. Louis, MO.

August 2009

- Frisvold, G. August 2009. Water as an economic resource. Tucson/Pima County Water and Wastewater Study Oversight Committee. Tucson, AZ.
- Overpeck, J.T. August 2009. Invited speaker at the “Water Symposium” hosted by the Arizona Hydrological Society and the American Institute of Hydrology. Scottsdale, AZ.

September 2009

- Crimmins, M. September 2009. Arizona DroughtWatch: How to get involved. Pima County Local Drought Impact Group. Tucson, AZ
- Ferguson, D., A. Taylor, and M. Crimmins. September 2009. Building partnerships to improve climate monitoring on the Colorado Plateau. US Global Change Research Program headquarters, (Washington, DC), NOAA Climate Prediction Center (Suitland, MD), and NOAA Headquarters brownbag seminar (Silver Spring, MD).
- Ferguson, D.B. September 2009. Monitoring drought for the 21st century in the Southwest. Navajo Nation Grazing Officials meeting. Window Rock, AZ. (invited)
- Frisvold, G. September 2009. Managing agricultural systems in a non-stationary world. 9th Annual Meeting of the NSF Science and Technology Center for Sustainability of semi-Arid Hydrology and Riparian Areas (SAHRA). Tucson, AZ.

- Garcia, M. and Hirschboeck K.K. September 2009. Integrating a flood hydroclimatology database with the Arizona hydrologic information system. 2009 Annual Symposium of the Arizona Hydrologic Society. Scottsdale, AZ.
- Garfin, G. September 2009. Climate change challenges and solutions for water managers. Arizona, Israeli, and Palestinian Water Management and Policy Workshop: Economic, Environmental, and Community Implications of Expanding Reuse and Desalination for Future Water Supplies. Tucson, AZ. (invited)
- Garfin, G. September 2009. Climate change in the Southwest. Tohono O'odham Community College Climate Enrichment Program Speaker Series. Sells, AZ. (invited)
- Garfin, G. September 2009. Gazing into the crystal ball: Climate change and future challenges for Arizona's water and environment. Arizona Chamber of Commerce 2009 Environmental and Sustainability Summit. Phoenix, AZ. (invited)
- Guido, Z. September 2009. What (some) resource managers are thinking: Tapping the institutional knowledge of the Fish and Wildlife Service regions 2 and 8 to address climate change. 9th Annual Meeting of the NSF Science and Technology Center for Sustainability of semi-Arid Hydrology and Riparian Areas (SAHRA). Tucson, AZ.
- Hartmann, H. September 2009. Reconciling Colorado River flow projections. Bureau of Reclamation meeting. University of Arizona, Tucson, AZ.
- Hirschboeck, K.K. September 2009. The potential of paleoflood information; Scenarios as tools for planning – paleo examples. Workshop on Paleohydrology, Climate Change and Water Resource Management. Decision Center for a Desert City, Arizona State University, Tempe, AZ. (invited)
- St. Hilaire, R. September 2009. Managed landscapes: Are they the key to future water security? Texas A&M University. College Station, Texas (invited).
- Woodhouse, C.A. September 2009. Background on using tree rings to reconstruct past flows; Reconstructed flows and floods for the Upper Colorado River Basin. Paleohydrology Workshop, Decision Center for a Desert City, Arizona State University. Tempe, AZ.

October 2009

- Colby, B. October 2009. Climate science and economics in tribal water negotiations and management. Workshop on Effects of Climate Change on Ecosystems and Societies: Native American and Hispanic Communities. Albuquerque, NM.
- Crimmins, M. October 2009. Update on observed drought impacts in Arizona. Arizona Governor's Drought Task Force Interagency Coordinating Group. Phoenix, AZ.
- Ferguson, D.B and M. Crimmins (co-presenters). October 2009. Building partnerships to improve climate monitoring on the Colorado Plateau. University of Arizona School of Geography and Development Colloquium, Tucson, AZ. (invited)
- Ferguson, D.B. October 2009. Native nations and changing climates. Tohono O'odham Community College Climate Enrichment Program speaker series. Sells, AZ. (invited)
- Garfin, G. October 2009. Climate change briefing with Hermosillo, Sonora Mayor Javier Gándara Magaña and his staff.
- Garfin, G. October 2009. Climate change in the Southwest: Looking ahead. Society for Conservation Biology Southwest Blueprint Policy Workshop. Flagstaff, AZ. (invited)
- Garfin, G. October 2009. Climate change projections and impacts: Future challenges for Arizona. 2009 American Planning Association (Arizona Chapter) Arizona State Planning Conference, session on Getting Real About Adapting to Climate Change in Arizona. Prescott Valley, AZ. (invited)
- Garfin, G. October 2009. Climate change projections and impacts: Future challenges for Arizona. Public lecture for Congregation Anshei Israel Hebrew High School. Tucson, AZ.
- Garfin, G. October 2009. Comportamiento y previsiones del clima en el Desierto de Sonora (Current and future Sonoran Desert climate change). Panel sobre Hermosillo y el clima. Comportamiento, amenazas, perspectivas. El Colegio de Sonora, Hermosillo, Sonora, México. (invited)
- Garfin, G. October 2009. Resultados de la encuesta (Online survey results). 3°Taller Para Instituciones y Actores Sobre Varieabilidad y Cambio Climático en la Costa Oeste de América del Norte. Puerto Peñasco, Sonora, Mexico.
- Garfin, G., M. Lenart, A. Ellis, and K. Murphy. October 2009. The Moisture Balance Drought Index and efforts to improve drought indicator reporting. U.S. Drought Monitor Forum. Austin, TX.
- Garfin, G., N. Pineda, and M. Barron. October 2009. Comportamiento y previsiones del clima en el Desierto de Sonora. Panel sobre Hermosillo y el clima. Comportamiento, amenazas, perspectivas. El Colegio de Sonora. Hermosillo, Sonora, México. (invited)
- Hartmann, H. October 2009. Systems thinking, adaptation, and scenario planning. Climate Friendly Parks Workshop. Grand Canyon National Park, AZ. (invited)

November 2009

- Ferguson, D.B. November 2009. Climate impacts in the U.S. Southwest. 2009. Native Peoples Native Homelands workshop. Mystic Lake, MN. (invited)
- Frisvold, G. November 2009. Effects of water shortages on Southwestern agriculture. International Water Resource Economics Consortium Meeting. University of California, Berkeley, CA.
- Frisvold, G. November 2009. Future scenarios for agriculture and water in Arizona. School of Sustainability Workshop, Arizona State University, Tempe, AZ.
- Garfin, G., N. Lee, and T. Rolfe. November 2009. CHANGE (Climate and Hydrology Academic Network for Governance and the Environment). American Water Resources Association Annual Water Resources Conference. Seattle, WA.
- Hartmann, H. November 2009. Confronting uncertainty through scenario planning. City of Tucson Climate Change Committee Adaptation Subcommittee Meeting. Tucson, AZ. (invited)

- Hirschboeck, K.K. November 2009. Uncertainty and floods: What can we learn from a 'bottom up' approach? Workshop on Decision Making in the Face of Climatic Uncertainty. Decision Center for a Desert City, Arizona State University, Tempe AZ. (invited)
- Overpeck, J.T. November 2009. Climate change overview presentation. Climate Change and Water Law workshop. Program sponsored by the National Judicial College. Reno, NV.
- Overpeck, J.T. November 2009. Southwest climate briefing to the U.S. National Academy Board on Earth Sciences and Resources. Oracle, AZ.
- Woodhouse, C.A. November 2009. Introduction to dendrochronology and tree-ring reconstructions of streamflow for the Colorado River Basin. Tucson Water, Tucson, AZ.

December 2009

- Ferguson, D. and M. Crimmins (co-presenters). December 2009. Building partnerships to improve climate monitoring on the Colorado Plateau. USGS Flagstaff Office. Flagstaff, AZ. (invited)
- Hartmann, H. December 2009. Understanding CPC seasonal outlooks; Understanding the quality of CPC products. Operational Climate Services Residential Training Courses, National Weather Service. Kansas City, MO.
- Overpeck, J. December 2009. The Colorado River Basin and the perfect storm ahead. Annual Meeting of the Colorado River Water Users Association. Las Vegas, NV. (invited)
- Overpeck, J.T. December 2009. Invited briefing of Arizona Department of Environmental Quality Director and senior staff on climate change in Arizona and the Southwest. Phoenix, AZ.
- Weiss, J.L., T. Ault, J.L. Betancourt, M.D. Schwartz, A. Macalady, G.T. Pederson, C.L. Castro, and J.T. Overpeck. December 2009. The post-1984 step change in spring temperatures and spring onset in the Western U.S.A.: Proximal and distant drivers. 2009 Fall Meeting of the American Geophysical Union. San Francisco, CA.
- Wilder, M., C. A. Scott, N. Pineda Pablos, R. G. Varady, G. Garfin, and J. McEvoy. December 2009. Adapting across boundaries: Knowledge, social learning and resilience in the US-Mexico border region. Earth Systems Governance Conference. Amsterdam, Netherlands.

January 2010

- Averyt, K., G. Owen, and K. Werner. January 2010. Developing and evaluating workshop frameworks to improve climate literacy. American Meteorological Society 90th Annual Meeting. Atlanta, GA.
- Brown, Tim, G. Owen, J. McLeod, and D.B. Ferguson. January 2010. Evaluation of fire forecast products to enhance U.S. drought preparedness and response using social network analysis. American Meteorological Society 90th Annual Meeting, 5th Symposium on Policy and Socio-economic Research. Atlanta, GA.
- Crimmins, M. January 2010. Drought monitoring in Arizona: The good, the bad, and the ugly. Little Colorado River Watershed Winter Meeting. Show Low, AZ.
- Ferguson, D.B. January 2010. Beyond the boundary: Knowledge networks and climate services. American Meteorological Society 90th Annual Meeting. Atlanta, GA.
- Garfin, G. January 2010. Climate adaptation partnerships in semiarid North America. American Meteorological Society 90th Annual Meeting, session on The Emergence of New Scientific Partnerships. Atlanta, GA.
- Garfin, G. January 2010. Climate change adaptation planning for Southwest ecosystems. American Meteorological Society 90th Annual Meeting, session on Mitigation and Adaptation to Climate Change. Atlanta, GA.
- Garfin, G. January 2010. Knowledge exchange and technology transfer. Southwest Fire Science Consortium workshop. Tucson, AZ.
- Garfin, G., C. Scott, A. Coles, A. Ray, D. Gochis, L. Farfan, T. Cavazos, K. Sammler, R. Varady, M. Wilder, N. Pineda, M. Montero, and A. Browning-Aiken. January 2010. Information flows and policy: Climate, cyclones, and adaptive water-resources management at the U.S.-Mexico border. American Meteorological Society 90th Annual Meeting. Atlanta, GA.
- Guido, Z. January 2010. Meeting demand for the undervalued climate service: Having ability to engage in medium-term projects. American Meteorological Society 90th Annual Meeting. Atlanta, GA.
- Hirschboeck, K.K. January 2010. A process-based "bottom-up" approach for addressing changing flood-climate relationships. National Academy of Sciences workshop on Global Change and Extreme Hydrology: Testing Conventional Wisdom. Washington, D.C. (invited)
- Owen, G. January 2010. Applications of social science methods: Evaluation and diffusion of innovations. Southwest Fire Science Consortium Workshop, Tucson, AZ.
- Owen, G., Averyt, K. and K. Werner. January 2010. Developing useful science: Methods for engaging stakeholders and evaluating integrated climate tools. American Meteorological Society 90th Annual Meeting. Atlanta, GA.
- Woodhouse, C.A. January 2010. Extended records of streamflow from tree rings and applications to water resource management. Osher Lifelong Learning Institute. Tucson, AZ.
- Woodhouse, C.A., J.J. Lukas, M. Mauzy, and J. Jones. January 2010. Paleoclimatic information for drought planning and decision making. American Meteorological Society 90th Annual Meeting, Fifth Symposium on Policy and Socio-Economic Research, Atlanta, GA. (invited)

February 2010

- Al-kofahi, S. February 2010. A decision-making tool to reduce drought vulnerability in urban landscapes. New Mexico State University Plant and Environmental Sciences seminar series. Las Cruces, NM.

- Crimmins, M. February 2010. Drought monitoring and preparedness in Arizona. Cienega Creek Watershed Partnership. Vail, AZ.
- Guido, Z. February 2010. Climate change and variability in the Southwest: Observations, impacts and projections. Arizona Department of Environmental Quality operator certification training. Tucson, AZ.
- McEvoy, J. and M. Wilder. February 2010. Technology and adaptation: Framing desalination in northwestern Mexico. Initiative on Climate Adaptation Research and Understanding through Social Sciences, Climate Vulnerability, and Adaptation Workshop: Theories and Cases. University of Illinois at Urbana Champaign. Champaign, IL.
- Overpeck, J. February 2010. Ongoing environmental change in the West, and what can we do to help? Sandia National Laboratory, Albuquerque, NM.

March 2010

- Colby, B. March 2010. Sharing best economic practices in adaptation planning. Eighth Annual Climate Prediction Applications Science Workshop. San Diego, CA.
- Ferguson, D.B. March 2010. Building partnerships for improved climate decision making in the Southwest: Two recent examples from the Climate Assessment for the Southwest. 8th Annual Climate Prediction Applications Science Workshop. San Diego, CA. (invited)
- Frisvold, G., B. Hurd, and C. Goehmans. March 2010. Policy Briefing on impacts of HR 2454 on Rocky Mountain agriculture. American Farmland Trust. Washington, DC.
- Garfin, G. March 2010. Climate adaptation partnerships: Examples from on the ground. CAMNet (Collaborative Adaptive Management Network) Annual Rendezvous. Tucson, AZ. (invited)
- Hirschboeck, K.K. March 2010. Floods, Climate, and “Cuisinart” Hydrology: A Recipe for Disaster? Biosphere 2 “Let’s Talk Science” Lecture Series, Biosphere 2, Oracle, AZ.
- Werner, K., G. Owen, and K. Averyt. March 2010. Toward a water resources outlook. Climate Prediction Applications Science Workshop. San Diego, CA.
- Wilder, M. (Session Organizer). March 2010. El Agua en las Regiones Fronterizas: gestion y politica. Primer Congreso, Red de Investigadores de Ciencias Sociales acerca del Agua (ISSA), Mexican Institute of Water Technology, Jiutepec, Morelos.
- Wilder, M., C. A. Scott, N. Pineda Pablos, R. G. Varady, G. Garfin, and J. McEvoy. March 2010. Adaptando al Cambio Climatico: El Agua y la Vulnerabilidad Urbana and la Frontera Mexico-EEUU. Primer Congreso, Red de Investigadores de Ciencias Sociales acerca del Agua (ISSA), Mexican Institute of Water Technology, Jiutepec, Morelos.
- Woodhouse, C.A. March 2010. Tree rings and Colorado River drought: A message from the past with implications for the future. Biosphere 2 Science Series, Biosphere 2, Oracle, AZ.

April 2010

- Butterworth, M.K., C.W. Morin, and A.C. Comrie. April 2010. Linking climate, vectors, and disease: A user-oriented approach to modeling mosquito populations. Association of American Geographers Annual Meeting. Washington, DC.
- Frisvold, G. April 2010 Effects of water shortages on Southwestern agriculture. National Agricultural Credit Conference. Phoenix, AZ.
- Garfin, G. April 2010. Across borders: Moving toward sustainable resource management at the nexus of water, climate, environment, and governance in the Americas. Association of American Geographers Annual Meeting. Washington, DC.
- Garfin, G. April 2010. Translational environmental research to provide decision and discussion support in North America’s border regions. Association of American Geographers Annual Meeting. Washington, DC.
- Guido, Z. April 2010. User-inspired science: Co-producing knowledge and communicating science about climate change. Knowledge Innovation at the Science-Policy Interface Workshop. San José, Costa Rica.
- McEvoy, J. and M. Wilder. April 2010. Political ecologies of desalination: Augmentation and adaptation in Spain and Mexico. Association of American Geographers Annual Meeting. Washington, DC.
- Morino, K. and R. Bark. April 2010. How will ICS impact Colorado water deliveries to Tucson? Tucson Water. Tucson, AZ.
- Overpeck, J. April 2010. Global Climate Change and the need for Remote Sensing for Detection and Adaptation. Annual conference of the American Society for Photogrammetry and Remote Sensing. San Diego, CA.
- Owen, G. April 2010. Social network analysis and evaluation of the NSAW Significant Fire Potential Outlook. National Seasonal Assessment Workshop. Boulder, CO.
- Wilder, M., C. A. Scott, N. Pineda Pablos, R. G. Varady, G. Garfin, and J. McEvoy. April 2010. Vulnerability and adaptation in a trans-boundary context: Binational approaches to assessing urban vulnerability and adaptation in the U.S.-Mexico border region. Association of American Geographers Annual Meeting. Washington, D.C.

Publications

Peer Reviewed Publications:

- Bark, R.H. and B.G. Colby. 2010. Climate, changing snowpack and the economics of winter recreation. In *Risk and resilience: The economics of climate-water-energy challenges in the arid southwest*. B.G. Colby and G. Frisvold (eds). Wash., DC: Resources for the Future Press.

- Basta, E. and B.G. Colby. 2010. Water market trends: Transactions, quantities, and prices. *The Appraisal Journal* 78 (1): 50-66.
- Colby B.G. and R. Bark. 2009. Inter-sectoral water trading as a climate change adaptation strategy. In *Water Resources Planning and Management*. Q. Grafton and K. Hussey (eds). Cambridge University Press.
- Colby, B.G. and G. Frisvold (eds). 2010 (forthcoming). *Risk and resilience: The economics of climate-water-energy challenges in the arid Southwest*. Washington, DC: Resources for the Future Press.
- Colby, B.G. and P. Tanimoto. 2010. Using climate information to improve electric utility load forecasting. In *Risk and resilience: The economics of climate-water-energy challenges in the arid southwest*. B.G. Colby and G. Frisvold (eds). Washington, DC: Resources for the Future Press.
- Conroy, J. L., J.T. Overpeck, J.E. Cole, and M. Steinitz-Kannan. 2009. Variable oceanic teleconnections to Western North American drought over the last 1200 years. *Geophysical Research Letters* 36: L17703. DOI: 10.1029/2009gl039558.
- Diaz-Caravantes, R.E. and C.A. Scott. 2009. Water management and biodiversity conservation interface in Mexico: A geographical analysis. *Applied Geography*. doi: 10.1016/j.apgeog.2009.10.003.
- Frisvold, G. and A. Murugesan (2010). Use of climate and weather information for agricultural decision-making. In *Risk and resilience: The economics of climate-water-energy challenges in the arid southwest*. B.G. Colby and G. Frisvold (eds). Washington, DC: Resources for the Future Press.
- Frisvold, G. and K. Emerick. 2010. Applying bargaining theory to western water transfers. In *Risk and resilience: The economics of climate-water-energy challenges in the arid southwest*. B.G. Colby and G. Frisvold (eds). Washington, DC: Resources for the Future Press.
- Frisvold, G. and S. Deva (2010). Irrigation technology choice: The role of farm size, energy costs, climate, and soils. In *Risk and resilience: The economics of climate-water-energy challenges in the arid southwest*. B.G. Colby and G. Frisvold (eds). Washington, DC: Resources for the Future Press.
- Frisvold, G. and S. Deva. 2010. Irrigator demand for information, management practices, and water conservation program participation: The role of farm size. In *Risk and resilience: The economics of climate-water-energy challenges in the arid southwest*. B.G. Colby and G. Frisvold (eds). Washington, DC: Resources for the Future Press.
- Frisvold, G.B., A. Boor and J.M. Reeves. (2009). Simultaneous diffusion of herbicide resistant cotton and conservation tillage. *AgBioForum* 12: 249-257.
- Garfin, G. 2009. Dry heat: An overview of climate changes and their impacts on North America's arid regions. *Sonárida* 27. Hermosillo, Sonora, Mexico. Available at <http://www.iesa.gob.mx/sonarida/default.htm>.
- Hirschboeck, K.K. 2009. Flood flows of the San Pedro River. In *Ecology and Conservation of the San Pedro River*. Juliet Stromberg and Barbara Tellman (eds.). Tucson: University of Arizona Press. Available at <http://fp.arizona.edu/kkh/pdfs/KK-Hirschboeck-2009-Flood-Flows-of-the-San-Pedro-River.pdf>
- Hirschboeck, K.K. 2009. Future hydroclimatology and the research challenges of a post-stationary world. *Journal of Contemporary Water Research and Education*. 142: 4-9. Available at <http://www.ucowr.siu.edu/updates/142/index.html>
- Jacobs, K., G. Garfin, and J. Buizer. 2010. New techniques at the science-policy interface: Climate change adaptation in the water sector. *Science and Policy* 36(10):791-798. DOI: 10.3152/030234209X481969.
- Jones, L. and B.G. Colby. 2010 (forthcoming). Weather, climate, and environmental water transactions. *Weather, Climate, and Society*.
- Karl, T.R., J.M. Melillo, and T.C. Peterson (eds.) (Overpeck was a co-author). 2009. *Global Climate Change Impacts in the United States*. Cambridge University Press.
- Mahmoud, M., Y. Liu, H.C. Hartmann, S. Stewart, T. Wagener, D. Semmens, R. Stewart, H. Gupta, D. Dominguez, F. Dominguez, D. Hulse, R. Letcher, B. Rashleigh, C. Smith, R. Street, J. Ticehurst, M. Twery, H. van Delden, R. Waldick, D. White, and L. Winter. 2009. A formal framework for scenario development in support of environmental decision-making. *Environmental Modeling and Software* 24(7):798-808.
- Morin, C. and A. C. Comrie 2010 (in press). Modeled response of the West Nile virus vector *Culex quinquefasciatus* to changing climate using the dynamic mosquito simulation model. *International Journal of Biometeorology*.
- Neff, J.C., A.P. Ballantyne, G.L. Farmer, N.M. Mahowald, J. Conroy, C.C. Landry, J. T. Overpeck, T.H. Painter, C.R. Lawrence, and R. Reynolds. 2008. Recent increases in eolian dust deposition due to human activity in the western United States. *Nature Geoscience* 1: 189-195.
- Norman, L., N. Tallent-Halsell, W. Labiosa, M. Weber, A. McCoy, K. Hirschboeck, J. Callegary, C. van Riper III, and F. Gray. (In review). Developing an online decision tool to assess the impacts of climate change and urban growth in the Santa Cruz watershed; Where we live, work, and play. Submitted to *Sustainability*.
- Weiss, J.L., C. L. Castro and J. T. Overpeck. 2009. The changing character of climate, drought, and the seasons in the Southwestern U.S.A. *Journal of Climate* 22: 5918-5932.
- Wilder, M. 2009. Drought risk and hazard. In *Sage Encyclopedia of Geography*. B. Warf (ed.). Los Angeles/London: Sage Publications.
- Wilder, M. Political and economic apertures and the shifting state-citizen relationship: Reforming Mexico's national water policy. In *Water Policy Entrepreneurs: A research companion to water transitions around the globe*. D. Huitema and S. Meijerink (eds). Cheltenham, UK: Edward Elgar.

Non Peer-Reviewed Publications:

- Al-Kofahi, S., G. Garfin, C. Fraise, M. Bean, and R. St. Hilaire. 2009. Establishing a decision making tool to reduce drought vulnerability in residential urban landscapes. *HortScience* 44: 1162.
- Anderson, C., D. Cayan, M. Dettinger, K. Dow, H. Hartmann, J. Jones, E. Miles, P. Mote, J. Overpeck, M. Shafer, B. Udall, and D. White, 2009. Climate services: The RISA experience. *A Report of the Regionally Integrated Sciences and Assessments Programs*. NOAA Climate Program Office. Washington, DC.

- Butterworth, M. 2010. *Dynamic mosquito simulation model (DyMSiM) user's guide and tutorial*. Draft available from author (mkbutter@email.arizona.edu); final version available online, summer 2010.
- Li, L. 2010. *State adoption of greenhouse gas emission targets and renewable portfolio standards*. Master's thesis, Department of Agricultural & Resource Economics, University of Arizona.
- Dhanireddy, P. 2010. *Crop insurance participation and disaster assistance: A simultaneous model*. Master's thesis, Department of Agricultural and Resource Economics, University of Arizona (expected May 2010).
- Diaz-Caravantes, R. 2009. *Water, rural livelihoods and global transformations: Geographies of peri-urban areas in Mexico*. Ph.D. dissertation, School of Geography and Development, University of Arizona.
- Enquist, C., A. Bradley, M. Cross, G. Garfin, D. Gori, P. McCarthy, and R. Oertel. 2010. *Jemez Mountains climate change adaptation workshop: Process, outcomes and next steps*. (Southwest Climate Change Initiative, April 2009 Workshop). Santa Fe: The Nature Conservancy. Available at http://www.nmconservation.org/projects/new_mexico_climate_change.
- Ferguson, D. and M. Crimmins. 2009. Who's paying attention to the drought on the Colorado Plateau? *Southwest Climate Outlook*. July 2009.
- Frisvold, G., W.P. Patton, and S. Reynolds. 2009. *Arizona solar energy and economics outlook: Report prepared for Arizona solar energy and economics summit*. Tucson, AZ: Arizona Research Institute for Solar Energy (AzRISE).
- Frisvold, G.B. and K. Konyar. 2009. *Impacts of water shortages on Arizona and southwestern agriculture: Market responses and policy options*. Report to the Marvin and June Morrison Chair in Agribusiness at Arizona State University. Available from authors.
- Garfin, G., K. Jacobs, and J. Buizer. 2009. Climate change adaptation lessons from the land of dry heat. In *Planning for an uncertain future—Monitoring, integration, and adaptation*. R.M.T. Webb and D.J. Semmens (eds.). Proceedings of the Third Interagency Conference on Research in the Watersheds: U.S. Geological Survey Scientific Investigations Report 2009-5049. Available at <http://pubs.usgs.gov/sir/2009/5049/>
- Garfin, G., N. Lee, V. Magaña, R. Steward, and J. McEvoy. 2009. *International workshop for CHANGE (Climate and Hydrology Academic Network for Governance and the Environment)*. Project Report for Foreign Affairs and International Trade Canada (DFAIT). Available in English and Spanish at: http://www.environment.arizona.edu/files/env/change/2009_workshop/report_english.pdf (or [_spanish.pdf](http://www.environment.arizona.edu/files/env/change/2009_workshop/report_spanish.pdf))
- Guido, Z., D. Ferguson, and G. Garfin. 2009. Putting knowledge into action: Tapping the institutional knowledge of U.S. Fish and Wildlife Service regions 2 and 8 to address climate change. August 2009. *Climate Assessment for the Southwest*.
- Hartmann, H.C., J. Schneider, and J. Wiener. 2009. *Supporting climate-responsive range management: Serving a diverse, distributed, and stressed sector*. White Paper submitted to NOAA Climate Program Office, Silver Spring, MD, 6 pp.
- Hurd, B., C. Goemans, G. Frisvold, and J. Stone. 2010. *Impacts of climate change legislation on agriculture in the rocky mountain states: Arizona, Colorado and New Mexico*. White Paper Prepared for the American Farmland Trust. Center for Agriculture in the Environment. Dekalb, I.L.
- Ochoa, R., T. Wordell, T. Brown, and D. Brown, 2010. *2010 National Seasonal Assessment Workshop for the Eastern, Southern & Southwest Geographic Areas (report)*, Shepherdstown, WV, January 26-28, 2010. Boise, ID: National Interagency Fire Center. Available at: http://www.predictiveservices.nifc.gov/outlooks/2010_ESAW_Report_FINAL.pdf
- Neely, B., P. McCarthy, M. Cross, Enquist, C., G. Garfin, D. Gori, D. Hayward, and T. Schulz. 2010. *Climate change adaptation workshop for natural resource managers in the Gunnison basin: Summary*. (Southwest Climate Change Initiative, December 2009 Workshop). Boulder: The Nature Conservancy. Available at http://www.nmconservation.org/projects/new_mexico_climate_change.
- O'Donnell, M. and B.G. Colby. 2009. *Dry-year water supply reliability contracts: A tool for water managers*. University of Arizona, Department of Agricultural and Resource Economics. Available at <http://ag.arizona.edu/arec/pubs/facultypubs/ewsr-dyo-Final.pdf>
- O'Donnell, M. and B.G. Colby. 2009. *Water auction design for supply reliability: Design, implementation, and evaluation*. University of Arizona, Department of Agricultural and Resource Economics. Available at <http://ag.arizona.edu/arec/pubs/facultypubs/ewsr-AUCTION-5-28-09.pdf>
- O'Donnell, M. and B.G. Colby. 2010. *Water banks: A tool for enhancing water supply reliability*. University of Arizona, Department of Agricultural and Resource Economics. Available at <http://ag.arizona.edu/arec/pubs/facultypubs/ewsr-Banks-final-2-11-10.pdf>
- Overpeck, J. 2009. Keep the west vibrant with a strong climate change policy. *Southwest Hydrology* 8(2): 24-30. (invited paper)
- St. Hilaire, R. and M.G. Al-Ajlouni. 2009. Linking landscape types to water use in residential landscapes. *HortScience* 44:1162.
- Subramaniam, B. 2010. *Carbon emissions and energy intensity: How and why states differ*. Master's thesis. Department of Agricultural & Resource Economics, University of Arizona.
- Wordell, T., R. Heffernan, T. Brown, and G. Garfin. 2009. *2009 National Seasonal Assessment Workshop for the Western States and Alaska (report)*, Boulder, CO, April 14-16, 2009. Boise, ID: National Interagency Fire Center. Available at: http://www.predictiveservices.nifc.gov/outlooks/2009_NSAW_WEST_REPORT.pdf
- Wordell, T., R. Heffernan, T. Brown, and G. Garfin. 2009. *North American Seasonal Assessment Workshop (NASAW) Canada, Mexico, and Western United States Outlook: 2009 (report)*, Boulder, CO, April 14-16, 2009. Boise, ID: National Interagency Fire Center. Available at: http://www.predictiveservices.nifc.gov/outlooks/2009_NASAW_WEST_REPORT.pdf
- Zeng, X., H. Gupta, P. Troch, P. Brooks, K. Jacobs, C. Castro, M. Crimmins, F. Dominguez, J. Duan, H. Hartmann, S. Kurc, R. Kursinski, T. Maddock, S. Mullen, J. Valdes, and C. Woodhouse. 2009. *Evaluation, improvement, and development of NOAA's hydroclimate services*. White Paper submitted to NOAA Climate Program Office, Silver Spring, MD, 10pp.