

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

Climate Assessment for the Southwest (CLIMAS) Phase 3

Annual Report for May 1, 2010–April 30, 2011

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CLIMAS Team

Investigators

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Stakeholders and Partners

Agua de Hermosillo
Albuquerque Journal
American Farmland Trust
American Meteorological Society
Arivaca Watershed Education Taskforce
AZ Cooperative Extension
AZ Dept. of Health Services
AZ Dept. of Transportation
AZ Dept. of Water Resources
AZ Electric Power Cooperative
AZ Game & Fish Dept.
AZ Local Drought Impact Groups
AZ Public Service Corporation
AZ State Climatologist
Barrio Sustainability Program
Carpe Diem
Central Arizona Project
City of Tucson Climate Change Advisory Committee
City of Nogales Water Utility
Colorado Basin River Forecast Center
Comisión Estatal del Agua-Sonora
Comisión Nacional del Agua
Cotton Incorporated
Denver Water
Desert Landscape Conservation Cooperative
Desert Research Institute
EcoAdapt
Environmental Defense
Environmental Protection Agency
-Air Quality
Federal Emergency Management Agency
Friends of the Santa Cruz River
Hopi Dept. of Natural Resources
Instituto Mexicano de Tecnología del Agua
Instituto Municipal de Investigación y Planeación de Nogales, Sonora

Interagency Climate Change Adaptation Task Force
Intercultural Center for the Study of Deserts and Oceans
International Panel on Climate Change Leadership Management Intl., Inc.
Mariposa Health Center
Metropolitan Water District of Southern California
Mid-Region Council of Governments
Multiagency Task Force of the Arizona Flood Warning System
Natl. Academy of Sciences
Natl. Park Service
Natl. Center for Atmospheric Research
Natl. Cotton Council
Natl. Drought Mitigation Center
Natl. Interagency Coordination Center
Natl. Interagency Fire Center-Predictive Services
Natl. Parks Conservation Association
Natl. Weather Service
The Nature Conservancy
Navajo Nation-Dept. of Water Resources
NM Cooperative Extension
NM Dept. of Health-Border Health
NM Environment Dept.-Air Quality
NOAA Earth Systems Research Lab
NOAA-NWS Climate Prediction Center
NOAA-NWS Climate Services Division
NOAA-NWS River Forecast Centers
NOAA-NWS Weather Forecast Offices
NOAA Science Advisory Board-Climate Working Group
NOAA-USDA Joint Agricultural Weather Facility
Northeast Regional Climate Center
Organismo Operador Municipal de Agua Potable

Physicians for Social Responsibility
Prescott Courier
ProNatura
Salt River Project
Santa Cruz County Health Dept.
Seattle Public Utilities
Secretaría de Medio Ambiente y Recursos Naturales
Secretaría de Protección al Ambiente-Baja California
Servicio Meteorológico Nacional
Sky Island Alliance
Sonoran Institute
Sonoran Joint Venture
Southern Nevada Water Authority
Southern Regional Climate Center
SW Coordination Center
SW Institute for Research on Women
Sustainable Tucson
Tucson Citizen
Tucson Community Food Bank
Tucson Water
United Way of Tucson
U.S. Bureau of Reclamation
U.S. Fish & Wildlife Service
U.S. Geological Survey
U.S. Institute for Environmental Conflict
U.S. Department of Agriculture
USDA-Natural Resources Conservation Service
USDA-Jornada Experimental Range
University of Arizona-Water Resources Research Center
Water Utility Climate Alliance
Western Governors' Association
Western Resource Advocates
Wildlife Conservation Society
YWCA Racial Justice Program

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2010
2011

Project Title	Lead P.I.	Key Result(s)	More Info
Climate Change Projections and Scenarios for the Southwest	H. Hartmann	Demonstrated a practical process for using scenario planning to consider climate change in the context of multiple stressors.	Page 3
Adaptation Strategies for Water and Energy Sectors in the Southwest	B. Colby	(1) Incorporating climate information can significantly reduce forecast error in electricity load forecasts. (2) Inclusion of climate variables improves model performance in estimating the economic value of water across wet and dry climate cycles.	Page 3
Patterns and Causes of Southwest Drought Variability	J. Overpeck	(1) The frequency, severity and duration of decadal megadroughts are influenced by variations in both the North Atlantic and tropical Pacific sea surface temperature. (2) State-of-the-art climate models likely underestimate future drought risk. (3) Current reconstructions of “worst possible drought” for the Colorado River underestimate the severity and duration of drought that has occurred.	Page 5
Hydroclimatology and Paleohydrology for Decision Support	K. Hirschboeck	Tropical storm precipitation was more important for producing the largest floods of record in southern Arizona than in non-coastal regions of Louisiana. This unexpected finding has implications for how future climate and storm behavior may impact flooding extremes in these two regions.	Page 5
Evaluation of Fire Forecast Products to Enhance U.S. Drought Preparedness and Response	G. Owen	(1) Predictive Services meteorologist communication in the Southwest has increased the use and number of applications for climate information in fire management. (2) Climate information has lengthened the planning window for fire management, enabling a more proactive approach to wildfire management.	Page 6
Climate Change Mitigation Strategies and Policies	G. Frisvold	(1) Additional water requirements needed to meet Arizona’s Renewable Energy Standard by 2025 using concentrated thermal solar power amount to 0.65% of state consumptive use. (2) Average water use per MWh of electricity for solar facilities about to be deployed in the Southwest U.S. is lower than water used for existing coal or nuclear plants. (3) Solar facilities can use considerably less water per acre than other commercial uses of land such as commercial real estate development or agriculture.	Page 11
Air Quality and Climate	D. DuBois	Rural visibility in New Mexico has improved over time due to controls on sulfur and nitrogen oxide emissions. Dust and fires remain the key sources of aerosols.	Page 12
Climate and Health	A. Comrie	Changes are occurring in West Nile virus mosquito season: the season itself is lengthening but populations may be depressed in the summer due to loss of habitat from drought or increased mortality from high temperatures.	Page 12

Selected Science Communication Highlights

Date	CLIMAS Investigator	Location	Activity
April 2011	J. Overpeck	Santa Fe, NM	Invited testimony before U.S. Senate Energy & Natural Resources Committee — Field Committee Hearing on current drought conditions affecting New Mexico and current scientific understanding of the impacts of climate change on water resources.
April 2011	H. Hartmann	Baltimore, MD	Presentation, “Constructing Regional Scenario Narratives to Confront Deep Uncertainty: Methods and Applications,” at the Specialty Conference on Managing Climate Change Impacts on Water Resources: Adaptation Issues, Options, and Strategies, hosted by the American Water Resources Association.
March 2011	D. Ferguson	Tucson, AZ	Invited faculty for the Institute for Tribal Environmental Professionals (ITEP) Southwest region climate change adaptation training for tribal environmental staff.
January 2011	C. Woodhouse	Abiquiu, NM	Presentation “Tree-Ring Reconstructions of Streamflow and Drought: Lessons from the Past for Future Planning,” at the US Forest Service Climate Change Workshop for the Santa Fe and Carson National Forests.
September 2010	J. Overpeck	Santa Fe, NM	Invited testimony before New Mexico Environmental Improvement Board — Cap-and-Trade Hearing on New Mexico Environment Department’s proposal to establish a greenhouse gas cap and trade program.
August 2010	G. Garfin	Tempe, AZ	Helped convene workshop, “Climate Downscaling and Water Availability,” as part of a series of workshops for scientists, water planners, and managers called: “Planning for climate change through an integrative approach to water-planning, climate downscaling, and robust decision-making.”
Fall 2010 and Spring 2011	Z. Guido	Across the Southwest	Multiple media mentions and interviews related to the new CLIMAS product, La Niña Drought Tracker.
Ongoing	G. Garfin & J. Overpeck	Tucson, AZ	CLIMAS members serving on committee to develop a Climate Change Mitigation and Adaptation Plan for the city of Tucson, including recommendations to help achieve the city’s greenhouse gas reduction commitments along with strategies to prepare for the effects of climate change on infrastructure and operations.
Ongoing	D. Ferguson & G. Garfin	Tucson, AZ	CLIMAS members serving on Tucson Water’s climate change adaptation planning committee, which is charged with helping the utility develop its first climate adaptation plan.
Ongoing	J. Overpeck, Z. Guido, J. Conroy, S. Truebe, M. Crimmins, and C. Routson	Internet	Twenty-three individual blog posts from May 2010—April 2011 on current, relevant issues regarding climate change and impacts for the U.S. Southwest. http://www.southwestclimatechange.org/blog

CLIMAS projects are organized into seven 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 this report, projects are highlighted within seven of these areas of focus:

Areas of Focus

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

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, K. Morino, J. Estes

Other Collaborators: L. Moriniere, K. Waser, and M. Crescioni-Benetiz (University of Arizona)

Partners: National Park Service, Carpe Diem West, Wildlife Conservation Society, Leadership Management International Inc.

Abstract: Through engagement with a variety of agencies and stakeholders, we are developing methods, resources, and tools for incorporating climate change and non-stationarity into planning efforts. Through this project and leveraged activities, we are: a) developing and applying scenario planning to address uncertainty of climate change and other stressors; b) evaluating needs and approaches for system-wide climate literacy training of National Park staff; c) identifying the needs and capacities of the water resources sector related to climate change and non-stationarity; d) evaluating methods for combining paleoclimatological information with historical observations and climate change projections; e) communicating uncertainty of projections of Colorado River flows; f) supporting the National Climate Assessment.

Methods: Scenario planning, workshops, interviews, surveys, quantile mapping, statistical analysis

Outcomes: (1) We demonstrated a practical process for using scenario planning to consider climate change in the context of multiple stressors. The approach is now being used within the National Park Service. (2) We developed a comprehensive curriculum for improving climate change literacy in the National Park Service.

Leveraged Funding Sources: National Park Service, Carpe Diem West

Adaptation Strategies for Water and Energy Sectors in the Southwest

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

Other Collaborators: M. Mealy and E. Basta (University of Arizona)

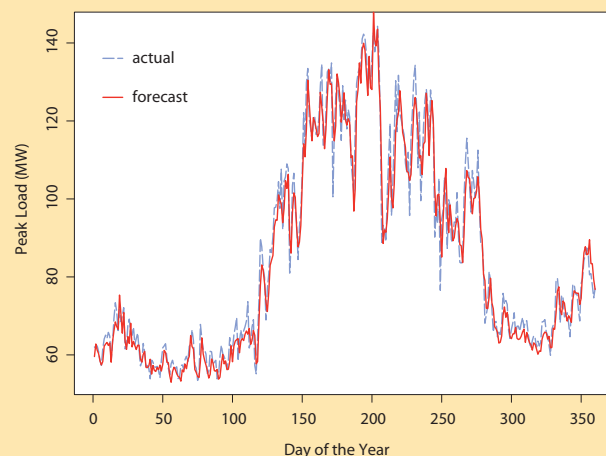
Partners: Arizona Department of Water Resources, Central Arizona Project, Salt River Project, Arizona Electric Power Cooperative, Arizona Public Service Corporation, Nature Conservancy-Western Regional Office, Environmental Defense, Sonoran Institute, ProNatura, Western Resource Advocates

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

Methods: Econometric analysis of climate, weather, socio-demographic, electricity-use and water-use data to a) improve electricity load forecasts and b) to assess the implications of misinterpretation of seasonal climate forecasts by water managers.

Selected results: (1) Incorporating climate information can significantly reduce forecast error in electricity load forecasts. (2) Inclusion of climate variables improves model performance in estimating the economic value of water across wet and dry climate cycles.

Leveraged Funding Sources: NOAA Sectoral Applications Research Program, University of Arizona Office of Arid Lands Studies, U.S. Bureau of Reclamation, Walton Family Foundation



State-of-the-art statistical modeling uses climate variables to help forecast electricity loads. Early results indicate that load forecasts that use climate data are more accurate. This information has the potential to help electric utilities and their customers adapt more cost effectively to the challenges climate change presents for energy suppliers and users.

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

CLIMAS Investigators: G. Frisvold, B. Colby, T. Gaston

Other Collaborators: S. Deva, K. Emerick, and A. Murugesan (University of Arizona)

Partners: U.S. Bureau of Reclamation, Central Arizona Project

Abstract: This project examines mechanisms for adapting to climate variability and change that include a) the use of water markets by agriculture and urban water utilities, b) the use of weather and climate information by agricultural producers, c) the adoption of improved irrigation technologies, and d) agricultural and other policy responses.

Methods: Multivariate regression analysis to estimate economic environmental determinants of irrigator behavior.

Results: (1) Irrigation district collective bargaining increases amount of water transferred. Improved irrigation efficiency does not necessarily increase transfers or conserve water. (2) Small farms are less likely to investigate irrigation improvements and use management-intensive irrigation scheduling. Larger farms use more data sources, especially private sources.

Leveraged Funding Sources: University of Arizona Water Sustainability Program, University of Arizona School of Natural Resources and the Environment, Central Arizona Project

Sky Island Climate Adaptation

CLIMAS Investigators: G. Garfin, Z. Guido

Other Collaborators: L. Misztal, J. Neeley, and M. Emerson (Sky Island Alliance); L. Hansen, R. Gregg, A. Score, and J. Hitt (EcoAdapt); L. Fisher, K. Caringer, G. Brooks, and M. McCaffrey (U.S. Institute for Environmental Conflict); R. Mesta, Sonoran Joint Venture; C. Conway and C. Hutchinson (University of Arizona); M. Falk (Fish and Wildlife Service); L. Meyers and C. Vojta (Desert Landscape Conservation Cooperative)

Abstract: Sky Island Alliance is working with CLIMAS investigators to connect planners and thinkers in natural resource management and conservation with experts on regional climate impacts and adaptation. Through this project we seek to increase resilience in the region by ensuring implementation of climate-smart, landscape-level management and conservation. Tools include a climate change adaptation survey, the Arizona Climate Change Network (Sky Island Alliance), and climate change adaptation workshops.

Methods: Focus groups, surveys, and “World Café” listening sessions.

Outcomes: (1) Catalog of adaptation and adaptive management projects in the Sky Island region of southern Arizona. (2) Assessment of vulnerabilities, adaptation planning and science needs.

Leveraged Funding Sources: Sky Island Alliance, University of Arizona Institute of the Environment

Adaptation and Resilience to Climate Change and Drought in the Urban Southwestern U.S. and Northern Mexico

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

Other Collaborators: J. Slack and R. Beaty (University of Arizona); Andrea Ray (NOAA-Earth System Research Laboratory); Patricia Romero-Lankao (National Center for Atmospheric Research); Bradley Lyons (Intl. Research Institute for Climate and Society); Alfonso Cortez-Lara (El Colegio de la Frontera Norte, Mexicali); Chris Watts (Universidad de Sonora)

Partners: Comisión Nacional del Agua, Servicio Meteorológico Nacional, Instituto Mexicano de Tecnología del Agua, Secretaría de Medio Ambiente y Recursos Naturales, Arizona Dept. of Water Resources, Central Arizona Project, Comisión Estatal del Agua-Sonora, Secretaría de Protección al Ambiente-Baja California, Tucson Water, City of Nogales Water Utility, Agua de Hermosillo, Organismo Operador Municipal de Agua Potable Alcantarillado-Nogales and Puerto Peñasco, Friends of the Santa Cruz River, Intercultural Center for the Study of Deserts and Oceans, Instituto Municipal de Investigación y Planeación de Nogales, Sonora

Abstract: Due to its rapid growth, industrialization, and climate characteristics, the Arizona-Sonora region along the U.S.-Mexico border is a highly vulnerable region in terms of socioeconomic and climate characteristics. Ensuring future water supply is the region's highest priority challenge. This research team worked closely with decision-makers, water managers, and disaster relief planners to conduct urban water vulnerability assessments of four urban climate change “hotspots” in the Arizona-Sonora region. Project outputs include a Binational Climate Summary for the Arizona-Sonora region (in English and Spanish) and a series of workshops.

Methods: Stakeholder interviews, online and person-to-person surveys, focus groups, and participant observation.

Leveraged Funding Sources: NOAA-Sectoral Applications Research Program, IAI-Global Change Research Program



Photo: Jeremy Slack, 2009

Climate Science

Patterns and Causes of Southwest Drought Variability

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

Other Collaborators: B. Udall (Western Water Assessment); J. Cole and D. Meko (University of Arizona)

Partners: International Panel on Climate Change, U.S. Bureau of Reclamation, Tucson Water, federal and state judges

Abstract: This project looks at observations of current and past drought, and the causes and impacts of these droughts by investigating the role of ENSO versus Atlantic sea surface temperatures in modulating drought, the exact nature of medieval megadroughts in the Four Corners region, the ecological impacts of drought, how well climate models simulate drought, and strategies for overcoming climate-model deficiencies in assessing future drought.

Methods: We are investigating past and future drought variability and impacts using climate models, paleoclimatic data (tree-ring and lake sediment), instrumental climate data, and biogeographical data.

Results: (1) The frequency, severity and duration of decadal megadroughts are influenced by variations in both the North Atlantic and tropical Pacific sea surface temperature. (2) State-of-the-art climate models (like those used by the IPCC) likely underestimate future drought risk. (3) Current reconstructions of “worst possible drought” for the Colorado River are, in fact, underestimates of the severity and duration of drought that has occurred, and that could occur in the Colorado River Basin.

Leveraged Funding Sources: National Science Foundation, NOAA-C2D2

Paleo-Southwest Monsoon Dynamics

CLIMAS Investigators: J. Overpeck, S. Truebe

Other Collaborators: J. Cole (University of Arizona)

Abstract: This work 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. Work to date has focused primarily on the use of cave formations (speleothems) to reconstruct past climate variability. Research includes investigating the use of lake sediments in New Mexico, Arizona, and Mexico to generate records that are complementary to the speleothem records. Multiple lakes have been visited and our efforts to find lakes that are appropriate for this work continues.

Results: Preliminary results indicate that climate change over the last 7000 years has been dominated by summer insolation change, just as is the case with the Asian monsoon.

Leveraged Funding Sources: U.S. Department of Defense, Science Foundation Arizona



Cave monitoring project, photo: J. Cardy

Hydroclimatology and Paleohydrology for Decision Support

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

Other Collaborators: M. Garcia, A. Coles, J. Culp, and N. Henderson (University of Arizona); J. Kiang and N. Paretto (U.S. Geological Survey); B. Cosson (Arizona Department of Water Resources); N. Steinberger (Federal Emergency Management Agency)

Partners: Members of the multiagency task force of the Arizona Flood Warning System

Abstract: This project explores innovative ways to address risk and resilience related to hydroclimatic extremes in both the upper and lower tails of streamflow probability distributions. Specific objectives include: (a) transferring information from tree-ring reconstructions about past extreme streamflow episodes to water managers for integration into operations; (b) constructing a flood hydroclimatology database for linking climate, floods, and paleofloods; (c) interacting with stakeholders to develop innovative ways to use the flood database information; and (d) exploring issues surrounding flood risk and human behavior to improve flood hazard management and flood warning practice.

Methods: Classification of floods based on storm type and climatic cause. Survey to determine perceived flood-climate link.

Results: Based on an interregional comparison of the flood hydroclimatology in southern Arizona and Louisiana, it was found that tropical storm precipitation was more important for producing the largest floods of record in southern Arizona than in non coastal regions of Louisiana. This unexpected finding has implications for how future climate and storm behavior may impact flooding extremes in these two regions.

Leveraged Funding Sources: NSF-Southern Arizona Geosciences Union for Academics, Research, and Outreach (SAGUARO)

Communicating Science

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

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

Partners: Seattle Public Utilities, Denver Water, Tucson Water, Metropolitan Water District of Southern California, Salt River Project, Southern Nevada Water Authority, Water Utility Climate Alliance, Climate Impacts Group, Western Water Assessment

Abstract: The primary objective of this project is to evaluate engagements of climate scientists and water managers 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.

Methods: We chose to form an advisory board for the project made up of a researcher and a water management professional from each of the three study cities. We used this advisory board to help guide the overall questions we asked in the data collection phase. Our data collection methods consisted of semi-structured interviews followed by a capstone workshop for the project that involved the project team, our advisory board, and water professionals and researchers not associated with the project but who have expertise in the incorporation of scientific information into water management decision making.

Leveraged Funding Sources: NOAA-Sectoral Applications Research Program

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

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

Other Collaborators: C. Kolden (University of Idaho); S. Trainor and P. Duffy (Alaska Center for Climate and Policy)

Partners: National Interagency Fire Center, Southwest Geographic Area Coordination Center-Predictive Services

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

Methods: Data was collected via online surveys and structured and semi-structured phone interviews. Social network analysis was used to study the patterns of relations between actors and groups in the network.

Results: (1) Communication on the part of Predictive Services meteorologists in the Southwest has increased the use and number of applications for climate information in fire management. (2) Climate information has lengthened the planning window for fire management. For example, many fire managers now begin thinking about the upcoming fire season much sooner than in previous years. This has enabled a more proactive approach to wildfire management, rather than a reactionary one.

Leveraged Funding Sources: NIDIS Coping with Drought 2009-2010



The network of fire management professionals in the Southwest who participated in the social network analysis. Note the central positions of the SWCC meteorologists—the most frequently cited contacts in the network—indicated by the two enlarged pink nodes.

Climate Literacy and Training Assessment

CLIMAS Investigators: Z. Guido, D. Ferguson

Abstract: Despite significant progress in improving climate literacy among a host of stakeholders, bringing climate change issues into 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 others less informed. This project involved a broad assessment across diverse user groups in the Southwest to identify training needs specific to different groups.

Methods: Literature review and semi-structured interviews with researchers and professionals.

Results: (1) Most climate training/education efforts are directed at K-12. (2) Urban planners are not covered by current climate training/education activities.

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

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

Partners: Tucson Water

Abstract: The main goals of the project are to share cutting-edge science with interested Tucson Water staff through an occasional lecture series, to foster discussions that help us understand what research is useful to Tucson Water operations, and to understand Tucson Water operations and issues more thoroughly.

Seasonal Climate Briefings

CLIMAS Investigators: G. Garfin, M. Crimmins, Z. Guido

Partners: Sample of organizations include: Albuquerque Journal, Arizona Dept. of Health Services, Arizona Dept. of Transportation, Arizona Game & Fish Dept., City of Tucson, National Interagency Coordination Center, Navajo Nation, Prescott Courier, Tucson Citizen, Tucson Water, NOAA-NWS Forecast Offices: Tucson, Albuquerque, Las Vegas, Phoenix, Flagstaff, El Paso, Colorado Basin River Forecast Center, Natl. Center for Atmospheric Research, Arizona State Climatologist, USDA-NRCS Natl. Water and Climate Center, Servicio Meteorológico Nacional, University of Arizona Dept. of Atmospheric Sciences

Abstract: Since Fall 2006, CLIMAS, in collaboration with Arizona Cooperative Extension, has provided online, interactive seasonal climate briefings for the Southwest and northern Mexico. The briefings have provided an interactive supplement to the monthly *Southwest Climate Outlook*, including an up-to-date summary of seasonal hydroclimate conditions and forecasts. The briefings provide an interactive forum for stakeholders to ask questions about climate information and receive answers immediately.

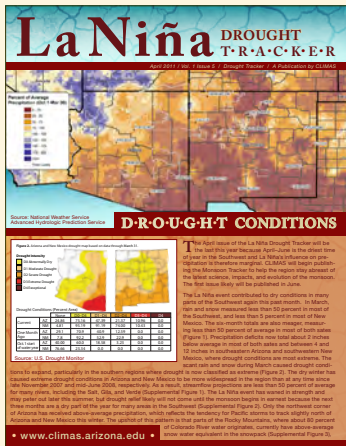
Results: (1) We served information to 25-30 participants, quarterly, via online briefing. (2) We compared and contrasted online briefing software, learning that managing traffic was best accomplished if questions were submitted using a chat window, rather than through telephone conversation.

National Climate Services Design, Support, and Evaluation

CLIMAS Investigators: H. Hartmann

Partners: American Meteorological Society, Interagency Climate Change Adaptation Task Force, NOAA Science Advisory Board Climate Working Group, NOAA-National Weather Service, Regional Climate Centers, State Climatologists, Carpe Diem West, National Academy of Sciences, National Research Council Committee on the Assessment of the NWS Modernization Program

Abstract: Over the past several years, discussion about the design and implementation of national climate services has increased substantially. In part, this is due to the success of RISA projects in working with stakeholders to define climate services needs and innovate new products, tools, and processes to support decision making related to climate variability and change. Recently, the design and implementation of national climate services has become a topic of significant focus within NOAA, the American Meteorological Society, and other organizations. The national discussion about climate services increasingly involves CLIMAS investigators. The emphasis is on (1) scaling up from local and regional experience to products and principles that can be implemented at a national level and for stakeholders not involved in any research projects, and (2) defining principles and processes for ensuring appropriate participation by the public, private, and academic sectors in providing services to a variety of applications.



La Niña Drought Tracker

CLIMAS Investigators: Z. Guido, G. Garfin, M. Crimmins, R. Macaulay

Abstract: One of the strongest La Niña events in the last 60 years became entrenched in August 2010 and signaled that the Southwest U.S. was likely going to experience below-average precipitation during the following winter. This event provided a good opportunity to develop a regional climate product to inform the U.S. Southwest of the evolving drought conditions and the underlying climate connections. The La Niña Drought Tracker was a two-page document published each month between December 2010 and April 2011, when La Niña impacts were most heavily experienced in the Southwest. It was disseminated to more than 1,600 subscribers and routinely viewed by more than 300 resource managers and decision makers each month, in addition to numerous media sources.

Outcomes: (1) The success of the Tracker is leading to the development of the Monsoon Tracker. (2) Comments from the initial user feedback survey include, "I manage water production for a medium sized city in northern Arizona that in part is dependent on surface-water runoff and snowpack.

Your periodic climate data assessments are a very valuable tool for short-and long-term planning."

The Southwest Climate Outlook

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

Other Collaborators: N. Selover (Arizona State Climatologist); S. Doster (University of Arizona Institute of the Environment)

Abstract: *The Southwest Climate Outlook (SWCO)* summarizes climate and weather information from disparate sources in nonscientific language, providing more than 1,600 people with timely climate-related information. Since SWCO's inception in 2002, stemming from the END InSight project, the publication has evolved into a tool for two-way communication with stakeholders and a platform for responding to needs throughout the region.

Methods: Six people contribute highlights for the Southwest Climate Outlook. Highlights are written by combining expert assessments with published graphics and information.



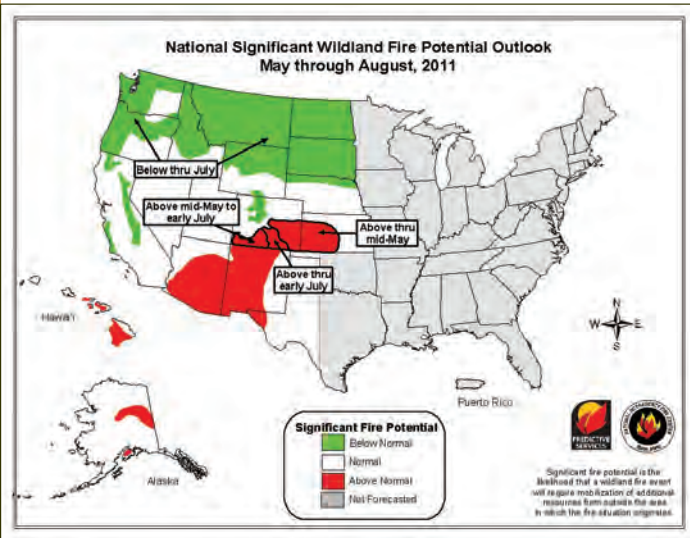
National/North American Seasonal Assessment Workshops

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

Other Collaborators: D. Zierden (Southeast Climate Consortium); T. Westerling (California Nevada Applications Program); K. Wolter (Western Water Assessment); J. Abatzoglou (Pacific Northwest Climate Decision Support Consortium); P. Duffy (Alaska Center for Climate and Policy); C. Leonard, J. Sullens, and I. Hirschfield (Natl. Interagency Coordination Center-Predictive Services); R. Heffernan (NOAA-NWS Office of Climate, Water, and Weather)

Partners: NOAA-Climate Prediction Center, NOAA-USDA Joint Agricultural Weather Facility, Western Regional Climate Center, Northeast Regional Climate Center, Southern Regional Climate Center, NOAA-National Weather Service

Abstract: The main goals of these workshops include a) producing seasonal fire potential outlooks, b) improving communication, coordination and knowledge exchange between climate scientists and fire professionals, and c) providing training to fire professionals on



climate-related topics. In 2010-2011, we experimented with convening the workshops through videoconferencing.

Leveraged Funding Sources: National Interagency Fire Center

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

CLIMAS Investigators: G. Owen

Other Collaborators: K. Averyt, T. Bardsley (Western Water Assessment); K. Werner (Colorado Basin River Forecast Center)

Abstract: This project evaluated NOAA water supply forecasts for the Upper Colorado River Basin by developing a series of rigorous user-needs assessments. Project goals include a) improving the usefulness of Colorado Basin River Forecast Center’s water supply forecasts for various user groups, b) expanding the user-base and enhancing their understanding of forecasts, and c) understanding the role of uncertainty and risk in interpreting and applying the forecast. The project used a variety of social science methods to help product developers identify, engage, and build relationships with diverse users, with the end goal of constructing more useful climate products.

Methods: Educational workshops, focus groups, decision games, surveys, and interviews. One of the more innovative methods we used were decision games, involving scenarios through which participants were asked to make various decisions.

Results: Significant changes were made to CBRFC’s webtool for streamflow forecasting based on information received at workshops and from the usability survey.

Leveraged Funding Sources: NOAA-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

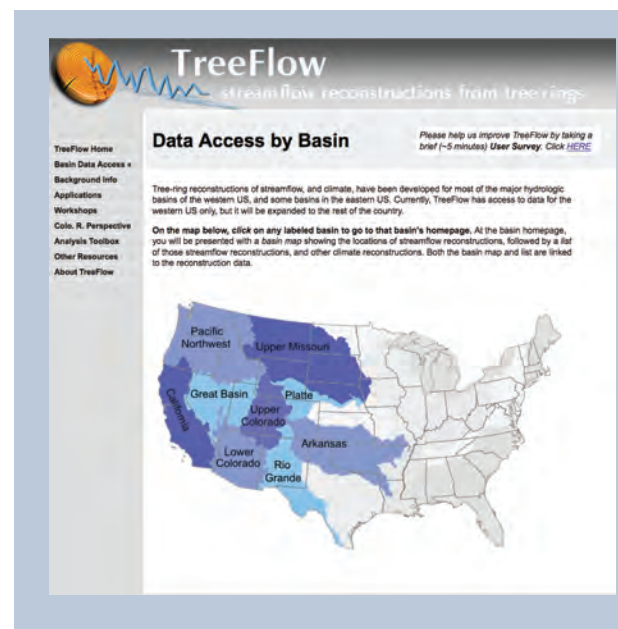
Other Collaborators: J. Lukas (Western Water Assessment); J. Littell (University of Washington)

Abstract: Paleohydrologic information collected from tree rings has become a valuable tool for drought planning and water resources management. The TreeFlow web site includes pages for accessing, evaluating, and downloading reconstructions of streamflow for a number of western river basins, examples of applications to water resource management, and information about past workshops for water resource managers (including instructional powerpoint presentations).

Methods: We contacted around 70 water resource managers during development for feedback about the tool. We demonstrated prototypes of the data tools to a set of workshop participants in Albuquerque (approx. 20 people).

Outcomes: A redesigned, enhanced, and expanded TreeFlow web page resource. The new TreeFlow contains a central data access point with background and FAQ information, and specific pages for major river basins.

Leveraged Funding Sources: NIDIS Coping with Drought 2009-2010



Urban Landscapes and Water Use

CLIMAS Investigators: R. St. Hilaire, D. DuBois, G. Garfin, S. Al-Kohafi

Other Collaborators: M. Bean (New Mexico State University); C. Steele (USDA-Jornada Experimental Range)

Partners: Mid-region Council of Governments, Cooperative Extension Service of New Mexico, Homeowners of Albuquerque

Abstract: This project aimed to classify residential, urban landscapes in Albuquerque, NM, using image processing software and Geographic Information System (GIS) with the intent of providing the backbone for a guide to water conservation and residential landscape policies. Goals included a) determining the spatial distribution of residential greenspace in Albuquerque's urban landscapes and b) developing a water budget calculator that is linked to the water budgets of the residential greenspace.

Results: (1) Residential greenspaces in Albuquerque were classified into eleven distinct categories. Overall accuracy of classification ranged from 80 to 90%. (2) Most landscapes in the six classified zip codes contained 75% trees and 25% shrubs and turf.

Forecast Evaluation and Application Research

CLIMAS Investigators: H. Hartmann, B. Colby

Other Collaborators: M. Mealy, J. Valdes, S. Mullen, and X. Zheng (University of Arizona)

Partners: NOAA-NWS Weather Forecast offices, NOAA-NWS River Forecast Centers, Climate Prediction Center

Abstract: Early in the CLIMAS project, dialogue with stakeholders clearly 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. Qualitative aspects of forecasts can be as important as any quantitative attribute in affecting how users interpret, apply, and ultimately judge probabilistic forecasts. Significant work is needed to develop forecast products that can be interpreted easily, correctly, and reliably without the need for special training. This project applies techniques for assessing forecast performance, qualitatively and quantitatively, with the intention of helping stakeholders appropriately align forecast use with measures of forecast skill. We are also examining the impacts of misinterpretation of forecast products.

Methods: Statistical analysis, interviews, and surveys.

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

Decision Support Tools: CLIDDSS, FET, DDIT, Paleo Toolkit and Others

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

Other Collaborators: S. Srinivasin, D. Martinez, and C. Hansen (University of Arizona)

Partners: NOAA-NWS Weather Forecast offices, NOAA-NWS River Forecast Centers, NOAA-NWS Climate Prediction Center, NOAA-NWS Climate Services Division, Carpe Diem West, Carolina Integrated Sciences and Assessments, Southeast Climate Consortium, Pacific RISA

Abstract: Barriers to the use of climate information can be crossed 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. In addition, tools that have proved successful in regional applications may be usefully extended to new regions. Rather than simply transfer the software, we develop partner capacities to implement collaborative software development protocols and processes. Tools developed, maintained, or extended under this project include the Climate Information Delivery and Decision Support System (CLIDDSS), the Forecast Evaluation Tool (FET), the Dynamic Drought Index Tool (DDIT) developed by Carolinas Integrated Sciences and Assessments (CISA), AgroClimate developed by the Southeast Climate Consortium (SECC), and the PaleoToolKit developed in conjunction with the Western Water Assessment (WWA) and CLIMAS-affiliated researchers.

Results: (1) Lack of software development capacity of operational agencies can limit transfer of research tools. (2) Collaborative programming is time consuming, but offers a way to build requisite institutional capacity.

Leveraged Funding Sources: Carpe Diem West

Drought

Arivaca Community Water Supply Drought Vulnerability Assessment

CLIMAS Investigators: Z. Guido, M. Crimmins

Other Collaborators: K. Uhlman (University of Arizona Water Resources Research Center)

Partners: University of Arizona Cooperative Extension, Arivaca Watershed Education Taskforce

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 main water source to drought. It also investigates options for sustainable water management.

Methods: Methods include data and statistical analysis of NWS weather stations, U.S. Geological Survey stream gauges, and local water information. Some outreach was also conducted, including several information sessions with the local water management group.

Results: (1) The young age of groundwater suggests that recharge has occurred in recent years from both the monsoon and winter precipitation. (2) The ephemeral arroyos appear to be an important conduit for recharging groundwater.

Leveraged Funding Sources: University of Arizona Water Resources Research Center, U.S. Geological Survey

Tribal Drought Information for Monitoring, Assessment, and Planning (Tribal DrI-MAP)



Drought conditions across the Four Corners region have exacerbated ongoing blowing dust problems. This picture from spring 2009 shows the results from a series of dust storms earlier that spring that buried rangelands across the Hopi and Navajo reservations.
Photo: Dan Ferguson

CLIMAS Investigators: M. Crimmins, D. Ferguson, C. Woodhouse, A. Meadow, H. Faulstich, A. Kimbrough

Other Collaborators: S. Marsh, W. Van Leeuwen, and B. Orr (University of Arizona, Arizona Remote Sensing Center)

Partners: Hopi Dept. of Natural Resources, Navajo Nation Dept. of Water Resources, Colorado Basin River Forecast Center

Abstract: The Hopi Tribe and Navajo Nation have been experiencing widespread and persistent drought conditions for more than a decade. Drought has impacted vegetation and local water resources in ways that threaten agricultural systems and ecosystems that are critical to supporting the Hopi and Navajo people. Limited hydroclimatological and ecological monitoring across the region has made it difficult to assess current drought impacts and anticipate future impacts. By working with Navajo and Hopi resource managers to develop better drought monitoring tools and tactics, we will help these two communities reduce their vulnerability to drought, cope with unavoidable drought impacts, and plan for long-term sustainability in the region.

Methods: Ethnographic methods, including indi-

vidual and group interviews to assess overall climate and drought information needs; an analysis of historic drought using both contemporary climate data and paleoclimatic reconstructions; remote sensing data to assess changes in land surface conditions related to drought impacts over the last two decades.

Leveraged Funding Sources: NOAA-Sectoral Applications Research Program, NASA Space Grant

Dendrochronology in the Tribal Lands of Northeast Arizona

CLIMAS Investigators: C. Woodhouse, H. Faulstich, M. Crimmins, D. Ferguson

Partners: Hopi Department of Natural Resources, Navajo Nation

Abstract: This project, a component of the Tribal DRI-MAP project, uses a collection of 8 tree-ring chronologies developed for the Four Corners region, coinciding with Navajo and Hopi tribal lands. The chronologies and the climate information they contain will be used to generate a set of outreach materials, both in the form of a handout or brief report written for a general audience and a presentation for tribal members. Other data products will be generated based on feedback from Hopi resource managers.

Leveraged Funding Sources: National Science Foundation

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

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

Partners: County-level local drought impact groups across Arizona

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—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 AZ Drought Watch 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: Individual interviews and an online survey were used in the evaluation process.

Results: The most prominent issue that has hindered participation in Arizona DroughtWatch was 'mission confusion' or lack of clarity regarding the specific goals and uses of DroughtWatch. This finding will help refine further efforts to engage and communicate with current and potential AZ DroughtWatch users.

Leveraged Funding Sources: National Drought Mitigation Center

State Drought Planning in the Western U.S.: A Multi-RISA-Agency-NIDIS Collaboration

CLIMAS Investigators: G. Garfin

Other Collaborators: B. Udall (Western Water Assessment) K. Redmond and D. Cayan (California Nevada Applications Program); D. White (Alaska Center for Climate Assessment and Policy); A. Steinemann and E. Miles (Climate Impacts Group); M. Hayes (National Drought Mitigation Center); M. Finucane (Pacific RISA)

Partners: National Integrated Drought Information System, Western Governors' Association (WGA), Western Regional Climate Center, state drought planning agencies

Abstract: This project brings together the western RISAs, agency partners, and state drought decision-makers, as well as other agencies and stakeholders. We will conduct group meetings and a workshop (through web-based techniques) to understand user needs for drought decision-making and the potential of climate and drought information. To gain a deeper understanding of drought issues and stakeholder needs, we will interview each of the WGA state drought managers to explore the following dimensions: a) use of drought information, b) value of information, c) indicators and triggers, d) responses and adaptations, e) interstate and intrastate planning, f) underserved populations, and g) effectiveness of programs.

Methods: Discourse analysis, interviews, and surveys

Leveraged Funding Sources: NOAA-Sectoral Applications Research Program

Economics & Livelihoods

Sectoral Impacts of Drought and Climate Change

CLIMAS Investigators: G. Frisvold, X. Ma

Other Collaborators: K. Konyar (California State University San Bernardino Department of Economics); S. Ponnaluru (Washington State University School of Economic Sciences Impact Center); S. Hecht (University of California Los Angeles School of Law)

Partners: National Parks Conservation Association

Abstract: This project examines the impacts of drought and climate change on climate-sensitive sectors in the Southwest, focusing on agriculture as well as outdoor recreation and tourism. The project also estimates the effects of drought and water shortages on farm income, production, prices, and employment; the effects of drought and water shortages on park visitation and outdoor recreation; and the effects of changes in recreation patterns on local economies.

Methods: The project uses a multi-commodity, multi-region agricultural sector model to assess impacts of water supply reductions or water price increases on Southwest agriculture. Multivariate regression analysis is combined with input-output modeling to examine the effects of climate, water availability, and gas prices on national park visits and local economies of park gateway communities. Multivariate regression results estimate how changes in climate, water availability, gas prices and other variables affect park visitation. The input-output model then is used to estimate how changes in park visits affect local sales, income, and employment.

Results: (1) The Southwest's agriculture, especially specialty crops is relatively resilient to water supply shocks. Specialty crops are grown primarily in western Arizona where irrigators have senior water rights. Crops produced in central Arizona, however, are more vulnerable to shocks. (2) Summer warming reduces visits to Southwest, but winter warming increases them, except in low-desert parks. Previous research of other areas suggests that park visitation may rise with climate change, but our results suggest this will not be the case in low-desert parks. The most significant climate-related impacts are reduced reservoir levels, which reduce water-based recreation.



Photo: George Frisvold, Yuma, AZ

Climate Change Mitigation Strategies and Policies

CLIMAS Investigators: G. Frisvold

Other Collaborators: L. Li and B. Subramaniam (University of Arizona)

Partners: Tucson Water, Navajo Nation

Abstract: This project involves economic evaluations of the effects of actual and proposed climate change mitigation policies. It compares and contrasts state energy and carbon-emission intensity and climate mitigation policies, seeking to examine how state resource endowments affect policy development and resource use. It also examines strategies to sequester carbon or reduce carbon emissions and examines the economic feasibility and resource constraints facing carbon emission-reduction strategies in the U.S. Southwest.

Methods: Multivariate regression analysis to examine state-level carbon emissions and adoption of emission-control policies. Growth decomposition analysis to estimate the contribution of population growth, economic growth, energy mix, and interstate electricity trade on carbon emissions at the state level.

Results: (1) Additional water requirements needed to meet Arizona's Renewable Energy Standard by 2025 using concentrated thermal solar power amount to 0.65% of state consumptive use. (2) Average water use per MWh of electricity for solar facilities about to be deployed in the Southwest U.S. is lower than water used for existing coal or nuclear plants. Two-thirds of the output is to come from low water-using solar technologies. (3) Solar facilities can use considerably less water per acre than other commercial uses of land such as commercial real estate development or agriculture.

Leveraged Funding Sources: Cotton Incorporated, Arizona Technology Research Initiative Fund

Health

Air Quality and Climate

CLIMAS Investigators: D. DuBois, R. St. Hilaire, B. Hurd, D. Akula

Other Collaborators: R. Fitzgerald (University of Texas El Paso Dept. of Physics); T. Gill (University of Texas El Paso Dept. of Geology); M. Green, D. Koracin, and R. Vellore (Desert Research Institute) M. Pitchford (NOAA Special Operations & Research Division and Environmental Protection Agency-Office of Air Quality) C. Runyon (New Mexico State University Cooperative Extension)

Partners: New Mexico State University Cooperative Extension, New Mexico Environment Dept.-Air Quality Bureau, New Mexico Dept. of Health-Border Health, NOAA-NWS Albuquerque and Santa Teresa Weather Forecast Offices



Photo: Dave DuBois

Abstract: We are investigating the connections between air quality, climate, and air mass transport patterns by tracking the frequencies, intensities, and locations of dust storms and wildfires over time. Additionally, we are supplying useful information to stakeholder agencies regarding the effects of climate on air quality. This involves an analysis of climate model output to help understand the potential effects of climate change in the regions surrounding the monitoring networks.

Methods: The Hysplit Lagrangian model to compute air mass trajectories. Analysis of the trajectory model output conducted using ArcGIS spatial data processing methods, regressions, and cluster analysis. Trends analysis of the trajectories and air quality data.

Results: Rural visibility has improved over time due to controls on sulfur and nitrogen oxide emissions. Dust and fires remain the key sources of most aerosols in New Mexico.

Leveraged Funding Sources: New Mexico Department of Health-Border Health, Office of the New Mexico State Climatologist, New Mexico State University College of Agricultural, Consumer, and Environmental Science

Climate and Health

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

Other Collaborators: P. Robbins, W. Van Leeuwen, E. Willott, and J. Jones III (University of Arizona)

Partners: Local public health departments, Santa Cruz County Health Department, Arizona Department of Health Services

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 (DyMSiM) 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: This project uses dynamic modeling (Morin and Comrie 2010) which simulates daily mosquito population dynamics as driven by climate and land cover inputs. Mosquito trapping is used to validate the model and characterize mosquito habitats in Tucson. Interviews with public health officials are used to understand how they conceptualize climate and disease in their health districts, and the use of dynamic modeling as a tool.

Results: (1) Simulated mosquito population dynamics in varying environments are similar to actual trapped data when aggregated to the weekly level. (2) Changes are occurring in West Nile virus mosquito season: the season is lengthening and populations are being and depressed in summer months due to loss of habitat from drought or increased mortality from high temperatures. (3) The model files for DyMSiM are available online, along with a website that contains user documentation and examples for how to use the tool, at <http://sites.google.com/site/dymsimmodel/home>

Leveraged Funding Sources: National Science Foundation – Urban Long-Term Research Area (ULTRA)



Assessing Regional Climate Service Needs Through Cooperative Extension

CLIMAS Investigators: M. Crimmins, D. DuBois, J. Brugger, G. Owen

Partners: Arizona Cooperative Extension, New Mexico Cooperative Extension

Abstract: Cooperative Extension (CE) has over 100 years of experience in delivering science-based decision support to clientele from multiple sectors. The CE structure enables a high level of connectedness and awareness of local issues and provides opportunities to assess local and multi-sector climate service needs. We are working through CE offices to capture snapshots of local climate science and service needs across rural areas of Arizona and New Mexico.

Methods: Interviews and focus groups with CE personnel (campus and county) and county-level 'opinion leaders' who have been identified by county extension directors.

Knowledge Exchange and Needs Assessment on Adaptation to Climate Change in the Colorado River

CLIMAS Investigators: G. Garfin, J. Galayda, G. Frisvold

Other Collaborators: K. Redmond (California Nevada Applications Program); E. Gordon (Western Water Assessment); A. Waple (NOAA-Natl. Climatic Data Center); T. Iseman (Western Governors' Association); E. Martin (University of Arizona Cooperative Extension); M. Walsh (United States Dept. of Agriculture); S. Moser (Susanne Moser Research & Consulting); N. Chhetri (Arizona State University); J. Smith (Stratus Consulting); L. Dilling (University of Colorado); L. Ethen (City of Tucson)

Partners: Diverse stakeholders from agriculture, ecosystem and water management sectors. A sample includes: Western Governors' Association, USDA, The Nature Conservancy, Carpe Diem West

Abstract: CLIMAS, in collaboration with Western Water Assessment and the California Nevada Assessment Program, will convene a workshop with key stakeholders and organizations from across a spectrum of sectors in the Colorado River Basin (CRB) to evaluate assessment capabilities and priorities, and to foster the development of a regionally coordinated network for ongoing assessment and adaptation. The workshop will focus on water as the major medium through which climate change impacts will manifest in the CRB, and will look broadly at adaptation strategies in relation to the agricultural, water management, and ecosystem management sectors. The workshop will take place in Boulder, Colorado, June 6-8, 2011. Follow-up from the workshop will include a summary report and webinar series designed to maintain communication, invite new participants, and provide opportunities for ongoing and new initiatives to present and describe their assessment and adaptation processes and challenges.

Climate Mitigation and Agriculture: Public Policy Education

CLIMAS Investigators: G. Frisvold, B. Hurd, Z. Mirza, X. Vu

Other Collaborators: C. Goemans (Western Water Assessment)

Partners: Cotton Incorporated, National Cotton Council, American Farmland Trust

Abstract: This project involves economic evaluations of the effects of actual and proposed climate change mitigation policies. It compares and contrasts state energy and carbon emission intensity and climate mitigation policies, seeking to examine how state resource endowments affect policy development and resource use. It also examines strategies to sequester carbon or reduce carbon emissions. The project estimates how proposed climate change mitigation legislation would affect costs and returns to agricultural producers in Arizona and New Mexico and investigates how changes in policy provisions could delay or reduce cost to agricultural producers.

Methods: Partial budgeting analysis is used to examine how changes in energy prices and energy-related inputs (primarily fertilizers) affect farm/ranch income. Analyses from DOE, USDA and FAPRI (Food and Agricultural Policy Research Institute) will be used to estimate input cost and output revenue shocks.

Results: (1) Provisions that provide protection to energy intensive trade-exposed (EITE) industries will substantially reduce and delay fertilizer price increases that agricultural producers would face. Fertilizer cost increases (the largest cost component of proposed climate legislation) would be delayed 15 years or more, allowing producers more adjustment time. (2) Crop producers benefit from higher output prices and income from selling agricultural offset credits. Retiring agricultural land for tree planting is the most likely source of offset income. Selling offset credits is more limited in the Southwest, but producers could benefit from higher output prices resulting from reduced production elsewhere.

Leveraged Funding Source: Cotton Incorporated

Poverty and Climate Change in the Southwest

CLIMAS Investigators: M. Wilder, D. Liverman, T. Osborne, A. Comrie, D. DuBois, R. St. Hilaire, L. Bellante, M. Gay-Antaki

Partners: United Way of Tucson, YWCA Racial Justice Program, Southwest Institute for Research on Women, Tucson Community Food Bank, Barrio Sustainability Program, Mariposa Health Center, Physicians for Social Responsibility, Sustainable Tucson, University of Arizona College of Public Health, University of Arizona Rural Health Program

Abstract: This research examines how the poor experience current climate variability in the Southwest and how the projected impacts of climate change would exacerbate many factors over the next decade, including potential impacts from climate mitigation and adaptation policy. Our objective is to engage with stakeholder organizations and analyze the linkage between poverty and climate in the southwestern U.S. and propose appropriate adaptive strategies.

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 files for DyMSiM are now available online, along with a website that contains user documentation and examples of how to use the tool. (<http://sites.google.com/site/dymsimmodel/home>)

Southwest Climate Outlook (SWCO)

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

This monthly online publication 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, forecasts, forecast verification, and news. (<http://climas.arizona.edu/forecasts/swoutlook.html>)

TreeFlow

C. Woodhouse, H. Hartmann, K. Hirschboeck

Updated tree-ring streamflow reconstructions available online 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. (<http://treeflow.info/toolbox.html>)

Border Climate Summary

G. Garfin, M. Wilder, R. Macaulay

This online publication provides specialized information, including climate summaries and forecasts, to over 1,600 stakeholders in the Arizona-Sonora region, in both Spanish and English. (<http://www.climas.arizona.edu/outlooks/bcs>)

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 online 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>)

Flood Hydroclimatology Tools

K. Hirschboeck

Tools are currently being developed to allow stakeholders to access information from the Arizona Flood Hydroclimatology database, to evaluate past floods and projected flood scenarios.

La Niña Drought Tracker

Z. Guido, G. Garfin, M. Crimmins, R. Macaulay

The La Niña Drought Tracker is a two-page document published electronically each month between December 2010 and April 2011 when La Niña impacts were most heavily felt in the Southwest. The publication was made available on the CLIMAS Website and was disseminated to over 1700 people, including resource managers, and decision makers. (<http://www.climas.arizona.edu/outlooks/drought-tracker>)

Dynamic Probability of Exceedance (POE) Seasonal Climate Outlook

H. Hartmann

Developed with NOAA-NWS Climate Prediction Center. Tool allows user to build and interact with multiple versions of the complex POE forecast product. The goal is to improve understanding of probabilistic climate outlooks and allow users to customize their probability forecast formats.

Small Grains Calculator

H. Hartmann

Developed for Mike Ottman, University of Arizona Cooperative Extension. Tool allows specialist to edit functions that map crop growth stage based on meteorological conditions from the AZMET network.

Paleo Toolkit

H. Hartmann, C. Woodhouse, K. Hirschboeck

- Drought Analog Visualization Tool. Finds analogs of droughts in the instrumental record with those from paleostreamflow reconstructions. Designed for integration into TreeFlow website.
- Gage Variability Tool. Visualizes recent streamflow observations compared to frequency percentiles defined by paleostreamflow reconstructions. Designed for integration into TreeFlow website.

Climate Information Delivery and Decision Support System

H. Hartmann

Significant redevelopment has been done to improve functionality for user groups. (<http://cliddss.arid.arizona.edu/CLIDDSSClient>)

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 currently used by the National Weather Service and the Climate Prediction Center. (<http://fet.hwr.arizona.edu/ForecastEvaluationTool/>)

Workshops

Workshop name	CLIMAS lead(s)	Date	Location	Partners
Climate Downscaling and Water Availability Workshop	G. Garfin	13 Aug 2010	Tempe, AZ	Arizona Water Institute, U.S. Bureau of Reclamation, the Central Arizona Project, the City of Phoenix, the Salt River Project, the City of Chandler, ASU Decision Center for a Desert City, the ASU Decision Theater, the UA Department of Hydrology and Water Resources, the UA Department of Atmospheric Sciences, UA School of Geography and Development
Climate Change Adaptation in the Arid Southwest: Workshop for land and resource management	G. Garfin, Z. Guido	20-21 Sept 2010	Tucson, AZ	Sky Island Alliance, Ecodapt, U.S. Institute for Environmental Conflict Resolution, U.S. Bureau of Reclamation
Tribal Climate Change Adaptation Planning and Inter-Governmental Coordination Workshop	D. Ferguson	5-6 Oct 2010	Boulder, CO	National Integrated Drought Information System, University of Colorado Law School
Restoring Rivers in the Southwestern U.S. and Northern Mexico: A binational conference on learning from the past for the benefit of the future	G. Garfin	7-9 Dec 2010	Tucson, AZ	World Wildlife Fund, Research Coordination Network for the Colorado River Delta, Instituto Nacional de Ecología, National Park Service, ProNatura
National Seasonal Assessment Workshop for Eastern, Southern, and Southwest Geographic Areas	G. Garfin	11-13 Jan 2011	Video Conference	National Interagency Coordination Center-Predictive Services, NOAA-CPC, NOAA-NWS, Southeast Climate Consortium
Knowledge to Action: Connecting climate science and resource management	J. Rice, D. Ferguson, C. Woodhouse	3-4 Mar 2011	Tucson, AZ	Climate Impacts Group, Denver Water, Seattle Public Utilities, Tucson Water, Western Water Assessment
Climate Change Adaptation Planning Training Workshop	D. Ferguson	8-10 Mar 2011	Tucson, AZ	Institute for Tribal Environmental Professionals
A New Generation Honors George Wright's Legacy: Climate change fellows and interns in the National Parks	G. Garfin	16 Mar 2011	New Orleans, LA	National Park Service, National Council for Science and the Environment
Between a Rock and a Hot Place: Climate change adaptation and resource management for the sky island region	G. Garfin, Z. Guido	13-14 Apr 2011	Tucson, AZ	Sky Island Alliance, Ecodapt, U.S. Institute for Environmental Conflict Resolution, U.S. Bureau of Reclamation
National Seasonal Assessment Workshop for the Western States, Alaska, and North America	G. Garfin	19-21 Apr 2011	Video Conference	National Interagency Coordination Center-Predictive Services, NOAA-CPC, NOAA-NWS, California Nevada Applications Program, Western Water Assessment, Pacific Northwest Climate Decision Support Consortium, Alaska Center for Climate and Policy
Poverty and Climate in the Southwest	M. Wilder	29 Apr 2011	Tucson, AZ	United Way of Tucson, YWCA Racial Justice Program, SW Institute for Research on Women, Community Food Bank, Barrio Sustainability Program, Mariposa Health Center, Physicians for Social Responsibility, Sustainable Tucson, City of Tucson Planning, UA College of Public Health
Arizona and U.S. Drought Monitoring and Decision Support Workshops	G. Garfin	Various	Kingman, Phoenix, and Tucson, AZ	National Drought Mitigation Center

Links to Other NOAA Programs

- Arizona and New Mexico state climatologists
- Climate Prediction Center
- NWS Climate Services Division
- NWS Colorado Basin River Forecast Center
- NWS WFOs in Tucson, Albuquerque, Las Vegas, Phoenix, Flagstaff, El Paso, Santa Teresa
- National Climatic Data Center
- NWS Office of Climate, Water, and Weather
- NOAA Earth Systems Research Laboratory
- NOAA Special Operations & Research Division
- NOAA-USDA Joint Agricultural Weather Facility
- Northeast Regional Climate Center
- Science Advisory Board Climate Working Group
- Southern Regional Climate Center
- Western Regional Climate Center
- CLIMAS currently works with most of the RISAs: Western Water Assessment, Climate Impacts Group, Southeast Climate Consortium, Alaska Center for Climate Assessment and Policy, Southern Climate Impacts Planning Program, California Nevada Applications Program, Carolinas Integrated Sciences and Assessments, Pacific RISA, Pacific Northwest Climate Decision Support Consortium

Cross RISA Collaborations

- Reconciling Projections of Future Colorado River Streamflow (Climate Impacts Group, California Nevada Applications Project, Western Water Assessment)
- Patterns and Causes of Southwest Drought Variability (Western Water Assessment)
- Knowledge to Action: An Assessment of the Transfer of Climate Science to Decision Making (Climate Impacts Group, Western Water Assessment)
- Evaluation of Fire Forecast Products to Enhance U.S. Drought Preparedness and Response (California Nevada Applications Program, Alaska Center for Climate and Policy)
- National/North American Seasonal Assessment Workshops (Southeast Climate Consortium, California Nevada Applications Program, Western Water Assessment, Pacific Northwest Climate Decision Support Consortium, Alaska Center for Climate and Policy)
- Developing Useful Science: Methods for Engaging Stakeholders and Evaluating Integrated Climate Tools (Western Water Assessment)
- TreeFlow: A Drought Planning Resource for Water Management in the Western U.S. (Western Water Assessment)
- Decision Support Tools: CLIDDSS, FET, DDIT, Paleo Toolkit and others (Carolina Integrated Sciences and Assessments, Southeast Climate Consortium, Pacific RISA)
- State Drought Planning in the Western U.S.: A Multi-RISA-Agency-NIDIS Collaboration (Western Water Assessment, California Nevada Applications Program, Alaska Center for Climate Assessment and Policy, Climate Impacts Group, Pacific RISA)
- Knowledge Exchange and Needs Assessment on Adaptation to Climate Change in the Colorado River (California Nevada Applications Program, Western Water Assessment)
- Climate Mitigation and Agriculture: Public Policy Education (Western Water Assessment)

Presentations

May 2010

Guido, Z. The impacts of climate change: what we're observing and what may occur. University of Arizona, Tucson, AZ.

Overpeck, J. Climate change, drought, and water implications for senior management. Tucson Water Lecture Series, Tucson, AZ.

Werner, K., G. Owen, and K. Averyt. Developing a toolkit for user engagement with climate services and water resources. NOAA Western Region SAFER Program (Societal Applications for Enhanced Readiness), Salt Lake City, UT.

June 2010

Crimmins, M. Precipitation variability in southern Arizona. Arivaca Water Education Task Force, Arivaca, AZ.

Crimmins, M. and D. Ferguson. Climate extension for the 21st century. Annual meeting of the Association for the Natural Resource Extension Professionals, Fairbanks, AK.

DuBois, D. Binational border area air quality. Border Breakfast Group, Mesilla, NM.

DuBois, D. Climate and drought in New Mexico. Project GUTS Workshop, Doña Ana Community College, Las Cruces, NM.

- DuBois, D. Climate in New Mexico. SC-2 Summer Teacher Workshop, New Mexico State University, Las Cruces, NM.
- DuBois, D. Status of drought in New Mexico. New Mexico Drought Task Force, Santa Fe, NM.
- Garfin, G., M. Cross, K. Brundiers, C. Enquist, R. Bark, D. Gori, P. Gober, P. McCarthy, and K. Jacobs. A plausible range: some observations on how resource managers are tackling climate change uncertainties. 2010 MTNCLIM Workshop, Blue River, OR.
- Guido, Z. Climate change in the Southwest: observation and projections. Air Quality in the Southwest Forum, Tucson, AZ.
- Hartmann, H. Scaling and sustainability of decision support tools. Environmental Evaluators Networking Forum, Washington, DC.
- Woodhouse, C. Dendrochronology and tree-ring reconstructions of streamflow for the Colorado River Basin. Tucson Water Citizens' Advisory Committee, Tucson, AZ.
- Woodhouse, C., J. Lukas, K. Hirschboeck, D. Meko, and J. Rice. Dendrohydrology: a tool for decision making in the face of climate uncertainty. World Dendro Conference, Rovaniemi, Finland.

July 2010

- Colby, B. Integrating climate change considerations into conservation planning. Kinship Conservation Fellows Annual Workshop, Bellingham, WA.
- DuBois, D. Climate trends in New Mexico. NM Supercomputing Challenge Workshop for Teachers, Socorro, NM.
- DuBois, D. New Mexico climate office. American Association of State Climatologists Meeting, South Lake Tahoe, CA.
- Guido, Z. Improving climate services in the West: evaluation lessons from CLIMAS. Federation of Earth Sciences Information Partners Conference, Knoxville, TN.
- Hartmann, H. Understanding CPC seasonal outlooks; Understanding the quality of CPC products. Operational Climate Services Residential Training Courses, National Weather Service, Kansas City, MO.
- Hirschboeck, K. Connecting flooding and climatic variability: what are the missing links? Water Across Interfaces – Consortium of Universities for the Advancement of Hydrologic Science, Inc. (CUAHSI) Second Biennial Science Meeting, Boulder, CO.
- Overpeck, J. Climate change, drought, and energy implications. Energy in the Southwest, Santa Fe, NM.

August 2010

- Al-Kofahi, S., C. Steele, D. VanLeeuwen, and R. St. Hilaire. Mapping land cover in urban residential landscapes using fine resolution imagery. Annual Meeting of the American Society for Horticultural Science, Palm Desert, CA.
- Al-Kofahi, S., R. St. Hilaire, Z. Samani, M. Bean, and L. Santon. Creating a landscape water budget calculator for a desert city. Annual Meeting of the American Society for Horticulture Science, Palm Desert, CA.
- Hartmann, H. Understanding CPC seasonal outlooks; understanding the quality of CPC products. Operational Climate Services Residential Training Courses, National Weather Service, Kansas City, MO.
- Overpeck, J. Ecological responses to abrupt climate changes: looking back to see ahead. Ecological Society of America Symposium, Pittsburgh, PA.
- Owen, G., K. Werner, and K. Averyt. A toolkit for user engagement. NWS Water Resources Workshop, Park City, UT.
- Sammler, K. Flood hydroclimatology as a flood management tool. WAS*IS Workshop, NCAR, Boulder, CO.

September 2010

- Al-Kofahi, S., R. St. Hilaire, Z. Samani, M. Bean, and L. Santon. Creating a landscape water budget calculator for a desert city. 51st International Plant Propagation Society, Bellingham, WA.
- Crimmins, M. Climate science extension: on the front lines in a warming world. Department of Soil, Water, & Environmental Science Seminar Series, University of Arizona, Tucson, AZ.
- Frisvold, G. and A. Barnhart. Solar energy's future in arizona and the impacts on water use. Water Resources Research Center Seminar, Tucson, AZ.
- Garfin, G. Projected Southwest climate changes. Climate Change Adaptation in the Arid Southwest: A Workshop for Land and Resource Management, Sky Island Alliance, Tucson, AZ.
- Hartmann, H. Using scenarios to confront deep uncertainty: methods and applications. Climate Change Adaptation in the Arid Southwest: a workshop for land and resource management, Sky Island Alliance, Tucson, AZ.
- Hartmann, H. Managing watersheds in the face of climate change. Healthy Headwaters Working Group Meeting, Salt Lake City, UT.
- Overpeck, J. Climate change and megadrought. Medieval Climate Conference, Lisbon, Portugal.
- Overpeck, J. Invited testimony on the NM Environment Department's proposal to establish a greenhouse gas cap and trade program. New Mexico Environmental Improvement Board, Cap and Trade Hearing, Santa Fe, NM.

October 2010

- Comrie, A. Catching climate fever: the changing environment of infectious disease. Ohio State University, Columbus, OH.
- DuBois, D. Binational air quality assessment project. EPA U.S.-Mexico-Chihuahua Rural Task Force, Columbus, NM.
- Garfin, G. Shouting "Maybe!" at the tops of our lungs: confronting uncertainty in planning for adaptation to a changing climate. The Wildlife Society's 17th Annual Meeting, Snowbird, UT.
- Guido, Z. Climate in the Southwest: past, present, and scenarios for the future. Arizona Dept. of Environmental Quality, Oracle, AZ.
- Guido, Z. Climate in the Southwest: past, present, and scenarios for the future. Arizona Electric Power Cooperative, Inc., Tucson, AZ.
- Hartmann, H. Incorporating risk and uncertainty: scenario planning. 17th Annual Conference of The Wildlife Society, Snowbird, UT.
- Hartmann, H. Supporting climate change in U.S. national parks through scenario planning. 17th Annual Conference of The Wildlife Society, Snowbird, UT.

- Hartmann, H. Working together to understand the effects of climate change in the Rockies of Montana, British Columbia, and Alberta. 10th Biennial Scientific Conference on the Greater Yellowstone Ecosystem, Mammoth, WY.
- Frisvold, G. and A. Barnhart. Water and land requirements for solar energy in the Southwest. University of Arizona, Fall Solar Seminar Series, Tucson, AZ.
- Overpeck, J. Climate change and drought. Climate Change and the Sonoran Desert, Saguaro National Park and the Arizona Sonora Desert Museum, Tucson, AZ.
- Overpeck, J. Climate change and drought. Western Coalition of Arid States (WestCAST) Annual Meeting, Tucson, AZ.
- Overpeck, J. Climate change, drought and the Colorado River. CHEVRON Climate Energy and Environment webinar series.
- Overpeck, J. Climate change and drought in the Southwest. Featured presentation: Collegiate and Campus Showcase at University of Arizona Homecoming, Tucson, AZ.
- Overpeck, J. Climate change and drought in the U.S. West. National Congress of American Indians, Albuquerque, NM.
- Pytlak, E., M. Crimmins, C. Castro, G. Garfin, and E. Jordan. Conveying medium range uncertainty forecasts to diverse stakeholders. National Weather Association Annual Meeting, Tucson, AZ.

November 2010

- DuBois, D. Binational border air quality study and areas for collaboration. University of New Mexico: Department of Health Air Quality Workshop, NM.
- DuBois, D. Border air quality assessment. Public meeting of the Environmental Protection Agency's Texas-New Mexico-Chihuahua Regional Workgroup, Anthony, NM.
- Frisvold, G. Insurance, incentives, and wildfire. Wildfire: Economics, Law & Policy, University of Chicago Law School and the Program on Economics Law and the Environment at the University of Arizona, Tucson, AZ.
- Overpeck, J. Climate change in the Southwest. Green Valley, AZ.

December 2010

- Ferguson, D. A few thoughts on regional climate services: the RISA model. Restoring Rivers in the Southwestern U.S. and Northern Mexico: World Wildlife Federation River Restoration Conference, Tucson, AZ.
- Garfin, G. Climate change services and incorporating adaptation into river conservation planning. Restoring Rivers in the Southwestern U.S. and Northern Mexico—World Wildlife Federation River Restoration Conference, Tucson, AZ.
- Hartmann, H. Decision support services. American Meteorological Society Committee on Climate Services, online webinar.

January 2011

- Comrie, A., J. Jones, P. Robbins, and W. van Leeuwen. ULTRA cool: hot new mosquito geographies. School of Geography and Regional Development, University of Arizona, Tucson, AZ.
- Dutton, J., R. Boyles, J. Day, J. Tuell, and H. Hartmann. Webinar on decision support services. American Meteorological Society 91st Annual Meeting, Seattle, WA.
- Ferguson, D. Development of experimental climate service networks: lessons from a multi-region project. American Meteorological Society 91st Annual Meeting, Seattle, WA.
- Guido, Z. Climate in the Southwest: how may it affect the region. Southwest Indian Agricultural Association Annual Conference, Laughlin, NV.
- Hartmann, H. and L. Welling. Using scenario planning to confront deep uncertainty: a case study from the crown of the continent. American Meteorological Society 91st Annual Meeting, Seattle, WA.
- Overpeck, J. Climate change and drought, USFS Climate Change Workshop, Santa Fe and Carson National Forests. Abiquiu, NM.
- Werner, K., K. Averyt, and G. Owen. User engagement for water resources forecasts: a framework for iterative communication. American Meteorological Society 91st Annual Meeting, Seattle, WA.
- Woodhouse, C. Drought history of the Southwest reconstructed from tree rings. Pima County Local Drought Impacts Group, Tucson, AZ.
- Woodhouse, C. Tree-ring reconstructions of streamflow and drought: lessons from the past for future planning. USFS - Climate Change Workshop, Santa Fe and Carson National Forests, Abiquiu, NM.

February 2011

- Butterworth, M. Climatic and social factors of dengue fever emergence along the Sonora–Arizona Border. Institute of the Environment Graduate Research Blitz, University of Arizona, Tucson, AZ.
- Crimmins, M. Drought monitoring and preparedness in Arizona. Arizona Cattlegrowers Quarterly Meeting, Phoenix, AZ.
- Faulstich, H. Tree-ring reconstruction of drought on tribal lands of northeastern Arizona. Institute of the Environment Graduate Research Blitz, University of Arizona, Tucson, AZ.
- Ferguson, D. CLIMAS Snapshots. NSF Decision Making Under Uncertainty: NOAA RISA Brainstorming Meeting, Tempe, AZ.
- Ferguson, D. Knowledge to action: an assessment of the transfer of climate science to decision making. NSF Decision Making Under Uncertainty-NOAA RISA Brainstorming Meeting, Tempe, AZ.
- Ferguson, D. Overview of CLIMAS Structure. RISA Program Manager meeting, Boulder, CO.
- Garfin, G. Impacts of climate change in the southwestern U.S. The Arctic is Melting and the Desert is Burning: Impacts Globally and Locally, Sponsored by Clean Air-Cool Planet, Avalon Trust, and Ambassador of Norway to the United States, His Excellency Wegger Chr. Strommen, Santa Fe, NM.

- Garfin, G. and K. Brundiers. Assessment of climate impacts to surface water resources for central Arizona. NSF Decision Making Under Uncertainty: NOAA RISA Brainstorming Meeting, Tempe, AZ.
- Hartmann, H. Scenario planning for adaptation to climate change: the National Park Service experience. School of Natural Resources and Environment, University of Arizona, Tucson, AZ.
- Meadow, A. Arizona DroughtWatch: Evaluating the first year. AZ Governor's Drought Task Force, Phoenix, AZ.
- Overpeck, J. Climate change and drought in the Southwest. Phoenix, AZ.

March 2011

- Crimmins, M. Drought impact monitoring in Arizona. Local drought impact groups in Kingman, Phoenix, and Tucson, AZ.
- Crimmins, M. Mid-winter climate review: December 2010-February 2011. Society of American Foresters, Forestry and Natural Resource Webinar Series.
- Faulstich, H. Tree-ring reconstruction of drought on tribal lands of Northeastern Arizona. Tree-Ring Day at School of Earth and Environmental Sciences EarthWeek, University of Arizona, Tucson, AZ.
- Ferguson, D. A brief overview of climate change in the Southwest. Tohono O'odham Prevention Coalition meeting, Sells, AZ.
- Ferguson, D. Adaptation fundamentals: some whats, hows, and whys of adapting to climate change. Institute for Tribal Environmental Professionals Climate Change Adaptation Training, Tucson, AZ.
- Ferguson, D. Overview of climate change: global to SW regional. Institute for Tribal Environmental Professionals Climate Change Adaptation Training, Tucson, AZ.
- Frisvold, G. and A. Barnhart. A drop in the bucket: water requirements need to meet Arizona's renewable energy standard. City of Tucson Water, Tucson, AZ.
- Frisvold, G. Resistance management and sustainable use of agricultural biotechnology. Fourth Berkeley Bioeconomy Conference, University of California, Berkeley, CA.
- Garfin, G. Climate adaptation in the Southwest. School of Natural Resources and the Environment, University of Arizona, Tucson, AZ.
- Guido, Z. Climate in the Southwest: CLIMAS efforts to help the region stay informed. Environmental Planning Advisory Committee, Pima Association of Governments, Tucson, AZ.
- Hartmann, H. Managing watersheds: short term and long term paths. Carpe Diem West, Denver, CO.
- Hartmann, H. Scenario planning in water management: evaluation of alternatives and the public process. George Wright Society Conference on Parks, Protected Areas and Cultural Sites, New Orleans, LA.
- Henderson, N. Causes of flooding in Louisiana vs. Arizona: similarities and differences. GeoDaze 39th Annual Geosciences Symposium, University of Arizona, Tucson, AZ.
- McLeod, J. Fire management and forecasting potential: climate, perception, and social networks. 71st Annual Meeting of the Society for Applied Anthropology, Seattle, WA.
- Overpeck, J. Climate change. Arizona Land and Water Trust, Tucson, AZ.
- Overpeck, J. Two invited talks on climatic extremes. Western States Water Council Symposium, San Diego, CA.

April 2011

- Butterworth, M. and M. Gay-Antaki. Environmental and social vulnerability to dengue fever in Nogales, AZ. 2011 Meeting of the Association of American Geographers, Seattle, WA.
- Faulstich, H. Tree-ring reconstruction of drought on tribal lands of northeastern Arizona. 2011 Meeting of the Association of American Geographers, Seattle, WA.
- Ferguson, D. Overview of climate change: global to SW regional. Inter Tribal Council of Arizona Tribal Air Quality Working Group meeting, Tempe, AZ.
- Hecht, S. and G. Frisvold. Insurance and economic tools for managing climate change-related risk. Strategies for Adapting to Climate Change conference, Tucson, AZ.
- Hartmann, H. Constructing regional scenario narratives to confront deep uncertainty: methods and applications. Specialty Conference on Managing Climate Change Impacts on Water Resources: Adaptation issues, options, and strategies. American Water Resources Association, Baltimore, MD.
- Hartmann, H. Understanding CPC seasonal outlooks; understanding the quality of CPC products. Operational Climate Services Residential Training Courses, National Weather Service, Kansas City, MO.
- Morin, C. and A. Comrie. Modeling climate-driven changes in a West Nile virus vector's population dynamics across the southern United States. 2011 Meeting of the Association of American Geographers, Seattle, WA.
- Overpeck, J. Climate Change. Between a Rock and a Hot Place: Climate Change Adaptation and Resource Management for the Sky Island Region. Sky Island Alliance, Tucson, AZ. (invited keynote)
- Overpeck, J. Invited testimony on current drought conditions affecting New Mexico and scientific understanding of the impacts of climate change on water resources. U.S. Senate Energy & Natural Resources Committee, full committee hearing, Santa Fe, NM.
- Owen, G. Fire Management and Significant Potential: climate, perception, and social networks. 2011 Meeting of the Association of American Geographers, Seattle, WA.
- Rice, J., D. Ferguson, and C. Woodhouse. Political waters: climate, science, and water management in the western United States. 2011 Meeting of the Association of American Geographers, Seattle, WA.
- Wilder, M. Poverty and climate in the southwestern United States. Social Justice Symposium, University of Arizona, Tucson, AZ.

Publications

Peer-Reviewed Publications

Bark, R. and B. Colby. 2011. Climate, changing snowpack, and the economics of winter recreation. *Risk and Resilience: The Economics Of Climate-Water-Energy Challenges In The Arid Southwest*. B. Colby and G. Frisvold (eds). Wash., DC: RFF Press.

- Brickey C., K. Engel, K. Jacobs, J. Matter, D. Luecke, M. Miller, J. Overpeck, and B. Udall. 2010. How to take climate change into account: a guidance document for adjudicating water disputes. *Environmental Law Reporter* 40: 11215-11228.
- Colby, B., E. Basta, and K. Pittenger. 2011. Temporary water transactions and climate change adaptation. *Risk and Resilience: The Economics Of Climate-Water-Energy Challenges In The Arid Southwest*. B. Colby and G. Frisvold (eds). Wash., DC: RFF Press.
- Colby, B. and G. Frisvold. 2011. The climate-water-energy nexus in the arid Southwest. *Adaptation and Resilience: The Economics of Climate-Water-Energy Challenges in the American Southwest*. B. Colby and G. Frisvold (eds). Wash., DC: RFF Press.
- Colby, B. and G. Frisvold. 2011. Modes of adaptation and regional resilience to climate change. *Adaptation and Resilience: The Economics of Climate-Water-Energy Challenges in the American Southwest*. B. Colby and G. Frisvold (eds). Wash., DC: RFF Press.
- Colby, B., L. Jones, and K. Pittenger. 2011. Economic tools for climate adaptation: water transaction price negotiations. *Risk and Resilience: The Economics Of Climate-Water-Energy Challenges In The Arid Southwest*. B. Colby and G. Frisvold (eds). Wash., DC: RFF Press.
- Colby, B. and P. Tanimoto. 2011. Using climate information to improve electric utility load forecasting. *Risk and Resilience: The Economics Of Climate-Water-Energy Challenges In The Arid Southwest*. B. Colby and G. Frisvold (eds). Wash., DC: RFF Press.
- Cole, K., K. Ironside, J. Eischeid, G. Garfin, P. Duffy, and C. Toney. 2011. Past and ongoing shifts in Joshua Tree support future modeled range contraction. *Ecological Applications* 21(1): 137-149. doi: 10.1890/09-1800
- Diaz-Caravantes, R. and E. Sánchez-Flores. 2011. Water transfer effects on peri-urban land use/land cover: a case study in a semi-arid region of Mexico. *Applied Geography* 31(2): 413-425. doi:10.1016/j.apgeog.2010.10.005
- Frisvold, G. and S. Deva. 2011. Irrigation technology choice: the role of farm size, energy costs, climate, and soils. *Adaptation and Resilience: The Economics of Climate-Water-Energy Challenges in the American Southwest*. B. Colby and G. Frisvold (eds). Wash., DC: RFF Press.
- Frisvold, G. and S. Deva. 2011. Irrigator demand for information, management practices, and water conservation program participation: the role of farm size. *Adaptation and Resilience: The Economics of Climate-Water-Energy Challenges in the American Southwest*. B. Colby and G. Frisvold (eds). Wash., DC: RFF Press.
- Frisvold, G. and K. Emerick. 2011. Applying bargaining theory to western water transfers. *Adaptation and Resilience: The Economics of Climate-Water-Energy Challenges in the American Southwest*. B. Colby and G. Frisvold (eds). Wash., DC: RFF Press.
- Frisvold, G. and K. Konyar. 2011. Water shortages in the southern mountain states: economic impacts on agriculture. *Adaptation and Resilience: The Economics of Climate-Water-Energy Challenges in the American Southwest*. B. Colby and G. Frisvold (eds). Wash., DC: RFF Press.
- Frisvold, G., X. Ma, and S. Ponnaluru. 2011. Climate, water availability, energy costs, and national park visitation. *Adaptation and Resilience: The Economics of Climate-Water-Energy Challenges in the American Southwest*. B. Colby and G. Frisvold (eds). Wash., DC: RFF Press.
- Frisvold, G. and A. Murugesan. 2011. Use of climate and weather information for agricultural decision-making. *Adaptation and Resilience: The Economics of Climate-Water-Energy Challenges in the American Southwest*. B. Colby and G. Frisvold (eds). Wash., DC: RFF Press.
- Frisvold, G. and J. Reeves. 2010. Resistance management and sustainable use of agricultural biotechnology. *AgBioForum* 13: 343-359.
- Garfin, G., J. Eischeid, M. Lenart, K. Cole, K. Ironside, and N. Cobb. 2010. Downscaling climate projections in topographically diverse landscapes of the Colorado Plateau in the arid southwestern United States. *The Colorado Plateau IV: Proceedings of the 9th Biennial Conference on Colorado Plateau Research, October 2007*. C. van Riper III, B. Wakeling, and T. Sisk (eds.), Tucson: UA Press.
- Garfin, G., N. Lee, V. Magana, R. Stewart, T. Rolfe, and J. McEvoy. (in press). International workshop for CHANGE: climate and hydrology academic network for governance and the environment. *Bulletin of the American Meteorological Society*. doi:10.1175/2010BAMS2927.1
- Jones, L. and B. Colby. 2010. Weather, climate, and environmental water transactions. *Weather, Climate, and Society* 2(3): 210-223.
- Morin, C. and A. Comrie. 2010. Modeled response of the West Nile virus vector *Culex quinquefasciatus* to changing climate using the dynamic mosquito simulation model. *International Journal of Biometeorology* 54: 517-529. doi:10.1007/s00484-010-0349-6.
- Norman, L., N. Tallent-Halsell, W. Labiosa, M. Weber, A. McCoy, K. Hirschboeck, J. Callegary, C. van Riper III, and F. Gray. 2010. Developing an ecosystem services online decision support tool to assess the impacts of climate change and urban growth in the Santa Cruz watershed: where we live, work, and play. *Sustainability* 2: 2044-2069. doi: 10.3390/su2072044.
- Overpeck, J., G. Meehl, S. Bony, and D. Easterling. 2011. Climate data challenges in the 21st century. *Science* 331(6018): 700-702.
- Overpeck, J., and B. Udall. 2010. Dry times ahead. *Science* 328: 1642-1643.
- Overpeck, J., M. Miller, and D. Liverman. 2011. Global climate change as a local phenomenon. *Navigating Climate Change in a Federal System*. E. Schlager, K. Engel, S. Rider (eds). Tucson: UA Press.
- Wilder, M. and G. Garfin. 2010. Drought hazard and risk. *Encyclopedia of Geography*. B. Warf (ed). London: Sage Publications, Inc.
- Wilder, M., C. Scott, N. Pineda, R. Varady, G. Garfin, and J. McEvoy. 2010. Adapting across boundaries: climate change, social learning, and resilience in the U.S.-Mexico border region. *Annals of the Association of American Geographers* 100(4): 917-928.

Non Peer-Reviewed Publications

- Al-Kofahi, S. 2011. *Mapping Land Cover in Urban Residential Landscapes: Implications for Water Budget Calculations*. Doctoral dissertation, Plant and Environmental Sciences, New Mexico State University.
- Al-Kofahi, S., C. Steele, D. VanLeeuwen, and R. St. Hilaire. 2010. Mapping land cover in urban residential landscapes using fine resolution imagery. *HortScience* 45(8): 93-94.
- Al-Kofahi, S., R. St. Hilaire, Z. Samani, M. Bean, and L. Stanton. 2010. Creating a landscape water budget calculator for a desert city. *HortScience* 45(8): 262-263.
- Basta, E. 2010. *Urban Water Supply Reliability and Climate Change*. Master's thesis, Dept. of Agricultural & Resource Economics, University of Arizona.
- Basta, E. and B. Colby. 2010. Water market trends: transactions, quantities, and prices. *The Appraisal Journal* 78(1): 50-69.
- Dhanireddy, P. 2010. *A Simultaneous Model of Disaster Assistance and Crop Insurance Participation*. Master's thesis, Dept. of Agricultural & Resource Economics, University of Arizona.
- Frisvold, G. In press. Implications of climate change legislation for U.S. cotton growers. *Proceedings of the Beltwide Cotton Conferences*. Memphis, TN: National Cotton Council.
- Guido, Z. 2010-11. 8 *Southwest Climate Outlook* feature articles. <http://www.climas.arizona.edu/outlooks/swco>
- Hurd, B., C. Goemans, G. Frisvold, and J. Stone (in press). *Estimated Impacts of Climate Change Legislation on New Mexico Agriculture*. Technical Report, Agricultural Experiment Station. Las Cruces, NM: New Mexico State University.
- Jones, L. and B. Colby. 2010. Farmer participation in temporary irrigation forbearance: portfolio risk management. *Rural Connections* 4(2): 43-48.
- Leonard, C., J. Sullens, T. Brown, and G. Garfin. 2011. *National Seasonal Assessment Workshop for the Eastern, Southern & Southwest Geographic Areas*. (Report) http://www.predictiveservices.nifc.gov/outlooks/2011_ESAW_Report.pdf
- Meadow, A. 2010. *Arizona DroughtWatch Program Evaluation*. (Report)
- Mealy, M. 2010. *The Misinterpretation of Climate Forecasts and Their Economic Impacts to the Agricultural Sector*. Master's thesis, Dept. of Agricultural & Resource Economics, University of Arizona.
- O'Donnell, M. 2010. *Innovative Water Supply Reliability Arrangements*. Master's thesis, Dept. of Agricultural & Resource Economics, University of Arizona.
- Overpeck, J., Z. Guido, J. Conroy, S. Truebe, M. Crimmins, and C. Routson. 2010-11. 23 Southwest Climate Change Network (SWCCN) blog posts. <http://www.southwestclimatechange.org/blog>
- Owen, G., K. Averyt, and K. Werner. 2010. *Using & Improving the Tools Available at the Colorado Basin River Forecast Center: A Toolkit for User Engagement* (Progress Report) <http://www.climas.arizona.edu/projects/developing-useful-science-methods-engaging-stakeholders-and-evaluating-integrated-climate--1>
- Subramaniam, B. 2010. *Per Capita Energy Consumption and CO2 Emissions: How and Why Do States Differ?* Master's thesis, Dept. of Agricultural & Resource Economics, University of Arizona.