CLIMAS
Climate Assessment for the Southwest

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

Climate Assessment for the Southwest (CLIMAS) Phase 3

Annual Report for May 1, 2011–April 30, 2012

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CLIMAS Team

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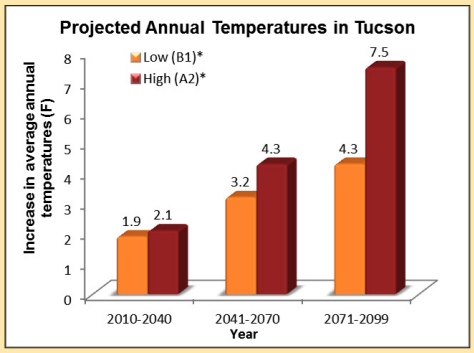
New Areas of Focus & Partnerships



Projected increases in average annual temperature, as a difference from the 1971-2000 average annual temperature (Weiss, 2011). The projections used a 16-model average for 12 gridpoints that intersect the spatial boundaries of the City of Tucson. Downscaled source data: Maurer et al. (2007).

Climate Change Analysis for the City of Tucson

CLIMAS Investigators: G. Garfin, G. Frisvold, A. Comrie, B. Colby, and J. Weiss

Other Collaborators: T. Kong (Univ. of Arizona); L. Ethen and J. Brown (City of Tucson-Office of Conservation and Sustainable Development)

Partners: City of Tucson Climate Change Committee, Cascadia Consulting Group Inc.

Abstract: Investigators are assisting the City of Tucson in conducting a vulnerability assessment regarding anticipated climate change impacts. They are synthesizing research related to local energy-water nexus issues; urban heat island effects; risk related to selected diseases; food security; and projected impacts and risks related to urban ecosystems and ecosystems surrounding the City.

Findings: Tucson temperatures are likely to increase. Precipitation projections show seasonal decreases and greater aridity. Both surface and groundwater supplies will face greater stress. Food security vulnerability is related to food imports and challenges to retooling Arizona food production. The likelihood of extensive tree mortality and wildfire risk is projected to increase. Connections within the water-energy nexus will be strained, resulting in increased water costs.

Deliverables: Publication – Garfin, G. and T. Kong. 2012. *Observed and Projected Climate Impacts for the City of Tucson.* A White Paper prepared for the City of Tucson Office of Conservation and Sustainable Development. March 2012. 43 pp.

Presentation – Carrillo et al. 2012. *Evaluation of value added using dynamically downscaled GCM product from NARCCAP historical and future climate projections.* NARCCAP Users Group Workshop, April 2012.

Leveraged Funding Sources: City of Tucson

The Social Construction of Climate Extremes in the Southwest

CLIMAS Investigators: G. Owen, D. Ferguson, and J. McLeod

Abstract: This project assesses the weather and climate scenarios that would most significantly impact the U.S. Southwest. A major objective is to understand how socially variable definitions of "extreme" climate and weather can inform a region-wide vulnerability assessment. An anticipated outcome of our project is that climate modelers at NOAA's Earth Systems Research Laboratory will use our data to develop models and forecasts addressing the extremes of highest concern in the region. This project will also provide information for the CLIMAS team as we move toward future research on extremes in the Southwest.

Deliverables: Presentation – *The Social Construction of Climate Extremes in the Southwest*. Annual Meeting of the Association of American Geographers. February 26, 2012, New York City.

Climate Boot Camps

CLIMAS Investigators: D. Ferguson and Z. Guido

Other Collaborators: J. Buizer (Univ. of Arizona); N. Chetri, R. Quay, M. Roy, and A. Reichman (Arizona State Univ.)

Abstract: This project has two goals: 1) provide useful, state-of-the-art knowledge about climate variability and change to urban resource managers so that climate science may be appropriately incorporated into long range decision processes; 2) work with urban managers to develop tangible products that will help planners and decision makers incorporate climate information into planning documents, processes, and policies. The project is comprised of two boot camp workshop series convened in Tucson and Phoenix. Each series will include a training session followed by a working session.

Leveraged Funding Sources: NOAA Sectoral Applications Research Program *(Primary funder of project)*

Selected Highlights from Research Activities and Stakeholder Collaborations

CLIMAS Investigator	Project Title	Highlight	More Info
B. Colby	Adaptation Strategies for Water and Energy Sectors in the Southwest	Preparation of two guidebooks, reviewed by stakeholder representatives: 1) *Measurement, Monitoring and Enforcement of Temporary and Seasonal Irrigation Forbearance Agreements*; 2) *Understanding the Value of Water in Agriculture: Tools for Negotiating Water Transfers* (Also published in Spanish).	Page 3
D. DuBois	Air Quality and Climate	Produced a community data portal using the UNIDATA THREDDS and RAMADDA server applications. This portal makes data sets publically available that had previously been archived at NMSU, the Center for Applied Remote Sensing in Agriculture, Meteorology and Environment (CARSAME), and New Mexico Climate Center.	Page 13
D. Ferguson	Tribal Drought Information for Monitoring, Assessment, and Planning	Co-presented an update on the collaboration between CLIMAS and the Hopi Dept. of Natural resources aimed at improving drought monitoring and planning in the Four Corners region of the Southwest with Clayton Honyumptewa, Manager of Hopi Dept. of Natural Resources at the July 2011 annual meeting of the Southest section of the Native American Fish and Wildlife Society Southwest in Santa Fe, NM.	Page 11
G. Garfin	Assessment of Climate Change in the Southwest United States	Coordinated 60+ authors and reviewers to produce a draft of the *Southwest Climate Assessment Technical Report: A Contribution to the National Climate Assessment*. The draft was delivered to the National Climate Assessment office on March 1, 2012.	Page 14
H. Hartmann	Forecast Evaluation and Application Research	With NOAA-Climate Prediction Center, developed the new Dynamic Probability of Exceedance Climate Outlook product. This product allows users to consider any probability or climate variable threshold, rather than standard terciles. The product supports engagement with decision makers about any probability threshold (e.g., 5% risk) or past extremes.	Page 8
M. Wilder	Managing Demand, Rethinking Supply: Adaptation, Conservation, & Planning in the Drought-prone SW U.S. and NW Mexico	Published a review of water research in the U.S.-Mexico border region: *Moving Forward from Vulnerability to Adaptation: Climate Change, Drought, and Water Demand in the Urbanizing Southwestern United States and Northern Mexico: Case studies in Ambos Nogales, Puerto Peñasco, Tucson, and Hermosillo.*	Page 5

Selected Research Findings from 2011-2012

Lead P.I.	Project Title	Key Result(s)	More Info
A. Comrie	Climate and Health	Both the *Ae. aegypti* (dengue vector) and *Cx. quinquefasciatus* (West Nile vector) mosquito models indicate a lengthening of the mosquito season under climate change scenarios. By including the viral pathogen into the models we can better assess the risk of increased disease transmission. Many environments can maintain a stable *vector* population but cannot sustain *viral transmission*.	Page 13
M. Crimmins & J. Brugger	Assessing Regional Climate Service Needs Through Cooperative Extension	Results from a series of focus groups across rural Arizona suggest: 1) short-term drought impacts ranchers more than any other group because of impacts on vegetation and water sources for cattle; and 2) farmers feel impacts of perceived recent changes in climate variability and the frequency of extreme events like hot and cold temperature extremes, wind events and shifts in growing season length.	Page 15
G. Frisvold	Climate Mitigation and Agriculture: Public Policy Education	The proposed American Clean Energy and Security Act of 2009 (H.R. 2454) legislation would entail a rise in costs for New Mexican agriculture. By 2020, energy costs are projected to rise 4-13% and fertilizer costs by 0.3-2%. Crop producers may experience improved revenues from higher crop prices, largely because carbon sequestration incentives would encourage retirement of cropland for tree planting in other parts of the country. Traditional ranchers would face higher feed costs with limited opportunity to participate in carbon-offset markets.	Page 16
Z. Guido	*La Niña Drought Tracker/Monsoon Tracker*	*La Niña Drought Tracker* was evaluated after its first season (2010-11) of publication. Readers believed that the *Tracker* improved their understanding of climate and drought. It also helped them better prepare for drought conditions. The success of the *Drought Tracker* led to the production of the *Monsoon Tracker* during the summer of 2011.	Page 7
K. Hirschboeck	Hydroclimatology and Paleohydrology for Decision Support	Preliminary findings show that "pineapple express/atmospheric river" (PE-AR) storms are only *one* of several types of winter storms that lead to flooding in Arizona. There are large geographic differences in their importance. PE-ARs were responsible for more floods in central and northern Arizona than in southern Arizona.	Page 6
G. Owen	Evaluation of Fire Forecast Products to Enhance U.S. Drought Preparedness and Response	Results from a social network analysis demonstrate that Predictive Services meteorologists occupy vital positions in the Southwest's fire management network. Their centrality measures demonstrate that in less than a decade they have become some of the network's most influential members, in terms of information production, distribution, and communication. Results also suggest an increasing trust on the part of fire managers to use climate and fire potential forecasts in their decision-making processes.	Page 8
J. Overpeck	Patterns and Causes of Southwest Drought Variability	A new 2200-yr long tree-ring record from southern Colorado suggests that medieval period megadroughts, well-documented in a number of different paleoclimatic records, are not unique. A megadrought in the 2nd century likely matched the severity of medieval droughts in the Southwest, and may have had similar causes.	Page 6
C. Woodhouse	Dendrochronology in the Tribal Lands of Northeast Arizona	Using 15 tree-ring chronologies from Navajo and Hopi tribal lands in the Four Corners region, results suggest that the instrumental record does not adequately represent the full range of natural regional climatic variability. Pre-instrumental drought events have far exceeded anything witnessed in the modern era. Many of the historically significant droughts of the past were not merely winter phenomena, but persisted through the summer season as well.	Page 11

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

Areas of Focus

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

Research and Stakeholder Collaboration Highlights

Adaptation & Vulnerability

Adaptation Strategies for Water and Energy Sectors in the Southwest

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

Other Collaborators: E. Schuster and A. Kerna (Univ. of Arizona)

Partners: Western Water Assessment, U.S. Bureau of Reclamation, U.S. Department of Agriculture, Arizona Dept. of Water Resources, Central Arizona Project, Salt River Project, Arizona Electric Power Cooperative, Arizona Public Service Corporation, Tucson Electric Power, 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 tools, as well as guidelines for using these tools, to enhance water supply reliability. Researchers are developing improved methods for predicting and adapting to climate impacts for the generation of electricity.

Findings: Peak season electricity loads are highly sensitive to moderate increases in summer temperatures. Electric utilities must prepare to meet these higher peak loads. Water providers must prepare for increased year-to-year and decadal variability in water supplies.

Deliverables: *Publications* – Bark et al. 2011. How Do Homebuyers Value Different Types of Green Space? *Journal of Agricultural and Resource Economics* 36(2): 395–415.

Preparation of two guidebooks, reviewed by stakeholder representatives: 1) *Measurement, Monitoring and Enforcement of Temporary and Seasonal Irrigation Forbearance Agreements,* May 2012*;* 2) *Understanding the Value of Water in Agriculture: Tools for Negotiating Water Transfers,* September 2011. Also published in Spanish: *Entendiendo el Valor del Agua en la Agricultura: Herramientas para Negociar Intercambios de Agua*

Project findings were communicated to NGO collaborators listed above.

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

Hydrologic Extremes and Water Management in a Warmer World – California Perspectives

CLIMAS Investigators: Z. Guido, D. Ferguson, K. Hirschboeck, and J. Overpeck

Other Collaborators: J. Jones (California Dept. of Water Resources)

Partners: California Nevada Applications Program, NOAA-Earth System Research Laboratory, Arizona State Univ.-Global Institute of Sustainability, Western Water Assessment, Univ. of Washington

Abstract: California has been a leader in climate change adaptation with state water sector agencies making good progress on adaptation related to water supply management and sea level rise. However, planning for flood management-related adaptation is complicated by hydrologic non-stationarity induced by climate change, a concept that challenges traditional standards of practice in hydrologic analysis and engineering design that have been in place for decades. This project consists of two workshops designed to: 1) identify applied science activities that could facilitate climate change adaptation to extreme events/severe weather and for flood management and 2) develop a road map for implementing those activities.

Deliverables: *Workshop* – Hydrologic Extremes and Water Management in a Warmer World – California Perspectives. Scripps Institute of Oceanography, Univ. of California San Diego. May 19-20, 2011, San Diego, CA.

Publication – Workshop Report from first meeting: http://www.climas.arizona.edu/files/climas/workshops/05-19-11/extremesworkshopreport-19may2011-final.pdf

Leveraged Funding Sources: California Department of Water Resources *(Primary Funder)*

Photo credit: Z. Guido

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

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

Other Collaborators: S. Deva, K. Emerick, and A. Murugesan (Univ. 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.

Findings: Using USDA Farm and Ranch Irrigation Survey data from Arizona and New Mexico, this project tested hypotheses about how farm size affects the use of water management information, investment in irrigation improvements, and participation in conservation programs. Reliance on low-cost, general information was common among all size classes, while larger operations relied more on private, tailored information. Larger operations were more likely to use directly provided data (e.g. media and Internet reports) than smaller operators, who relied more on information provided by intermediaries.

Using data from a sub-sample of the National Agricultural, Food, and Public Policy Preference Survey, the project assessed use of weather data for agricultural decision-making by 284 Arizona farmers and ranchers. Producers with diversified agricultural production were more likely to use data for timing of planting, cultivation, and harvest. Weather data use was lower among producers with greater reliance on off-farm income. Producers who rated government risk-management programs as important used weather data for more decisions. Access to satellite TV increased data use, but access to the Internet did not.

Central Arizona Project
Photo source: http://www.usbr.gov/lc/region/img/gallery/CAP/canal.jpg

Deliverables: Publications – Frisvold, G. and S. Deva. 2012. Farm Size, Irrigation Practices, and Conservation Program Participation in the U.S. Southwest. *Irrigation and Drainage*. (In press)

Gaston, T. 2012. *Agricultural Water Demand along the Lower Colorado River Mainstem: Developing and Testing a Three-Model Approach for Econometric Analysis*. Master's Thesis. Univ. of Arizona, Department of Agricultural & Resource Economics.

Frisvold, G. and A. Murugesan. 2012. Use of Weather Information for Agricultural Decision-Making. *Weather, Climate & Society*. (In Review)

Leveraged Funding Sources: Univ. of Arizona-Water Sustainability Program, Central Arizona Project

Sky Island Climate Adaptation

CLIMAS Investigators: G. Garfin and Z. Guido

Other Collaborators: L. Misztal, J. Neeley, and M. Emerson (Sky Island Alliance - *Primary Project Leaders*); 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 (Univ. 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.

Findings: 1) Chief climate threats identified in workshops included increasing temperatures; precipitation changes including amount, seasonal timing, and intensity; and drought. Participants noted that megadrought could be a game-changer for Southwest ecosystems, due to the potential for rapidly crossing ecosystem thresholds into new quasi-equilibrium states, such as from pine-oak forests to oak scrub woodlands. 2) Uncertainties in climate change projections provided little impediment to the preliminary discussions about impacts and identification of adaptation strategies. 3) Participants identified actionable adaptation goals that piggyback on existing management, restoration or public education priorities, and can be implemented in the short-term using familiar management tools.

Deliverables: Publication – Misztal et al. 2012. Responding to Climate Change Impacts in the Sky Island Region: From Planning to Action. *Proceedings of the Third Conference on Biodiversity and Management of the Madrean Archipelago.* (In review)

Leveraged Project – Stemming from the workshop series is the *Spring and Seep Inventory, Assessment, and Management Planning Project* to develop new information on the current biological, hydrological, geomorphological, and management status of springs and seeps. The project is being implemented by Sky Island Alliance in coordination with several regional resource managers, including Pima County, the U.S. Forest Service, and the National Park Service.

Leveraged Funding Sources: Sky Island Alliance (*Primary Funder*), Univ. of Arizona-Institute of the Environment

Climate Change Projections and Scenarios for the Southwest

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

Other Collaborators: K. Wiltshire (Carpe Diem West); M. Cross and E. Rowland (Wildlife Conservation Society); G. Bodner and K. Simms (Cienegas Watershed Partnership); R Moss (National Climate Assessment Development and Advisory Committee)

Partners: National Park Service, U.S. Fish and Wildlife Service

Abstract: Through engagement with a variety of agencies, this project develops methods, resources, and tools for incorporating climate change and non-stationarity into planning efforts. Through this project and leveraged activities, we: a) develop and apply scenario planning to address uncertainty of climate change and other stressors; b) evaluate needs and approaches for system-wide climate literacy training of National Park staff; and c) identify the needs and capacities of the water resources sector related to climate change and non-stationarity.

Findings: Scenario planning is readily accepted by a variety of resource managers as a useful process for considering high levels of uncertainty in their decision-making, beyond the use of downscaled global climate model projections.

Deliverables: Publications – Garfin et al. 2011. Climate-Friendly Park Employees: The Intermountain Region's climate change training assessment. *Park Science* 28(1): 30-36.

Hartmann et al. 2011. Appendix 4: Participatory scenario planning in regional and sectoral stakeholder activities in the National Climate Assessment. In *Scenarios and Regional Summaries, Report to National Climate Assessment Development and Advisory Committee.* Ad hoc Working Group 3. May 13, 2011. Washington, DC.

Mahmoud et al. 2012. Development and testing of stakeholder-driven water resources management scenarios for the Southwestern United States. *Environmental Modeling and Software*. (Submitted)

Presentations – Four presentations to a variety of stakeholder groups, such as: Constructing regional scenario narratives to confront deep uncertainty: methods and applications. Sonoita Valley Science on the Plain. Cienegas Watershed Partnership, Audubon Research Ranch, AZ, June 4, 2011.

Three presentations to academic audiences, such as: Managing watersheds – short and long term paths. Navigating the Future of the Colorado River, Martz Conference. Natural Resources Law Center, Univ. of Colorado-Boulder, Boulder, CO, June 8-10, 2011.

Leveraged Funding Sources: National Park Service, Carpe Diem West

Managing Demand, Rethinking Supply: Adaptation, Conservation, and Planning in the Drought-prone Southwestern U.S. and Northwest Mexico

CLIMAS Investigators: M. Wilder, G. Garfin, A. Quijada-Mascarenas, G. Frisvold, S. Kelly, and G. Owen

Other Collaborators: R. Varady, C. Scott, D. Austin, K. Flessa, L. López-Hoffman, M. Vásquez, H. Bruckner, J. Correia, and S. Marley (Univ. of Arizona); N. Pineda (El Colegio de Sonora); Patricia Romero-Lankao (National Center for Atmospheric Research); L. Brito-Castillo (Northwest Center for Biological Research–Mexico); F. Lara Valencia (Arizona State Univ.); L. Norman (U.S. Geological Survey); M. Carmen Lemos (Univ. of Michigan); B. Lyon (International Research Institute for Climate and Society)

Abstract: This project focuses on building adaptive capacity for water management in the transboundary region; understanding the role of climate information within governance networks; developing innovations in communicating climate science; and developing of a set of metrics for assessing adaptive capacity in arid and border regions. Study sites include Tucson, Ambos Nogales, Hermosillo, and the Delta/Upper Gulf of California.

Deliverables: Publications – Wilder, M. et al. 2012. *Moving Forward from Vulnerability to Adaptation: Climate Change, Drought, and Water Demand in the Urbanizing Southwestern United States and Northern Mexico: Case studies in Ambos Nogales, Puerto Peñasco, Tucson, and Hermosillo.* Tucson, AZ: Udall Center Publications.

Transborder Climate: Adaptation Without Boundaries/Clima Transfronterizo: Adaptación sin Fronteras. 2012. Newsletter report on research and forecasts related to climate and its impacts in the transboundary United States-Mexico border region. http://www.climas.arizona.edu/outlooks/tbc

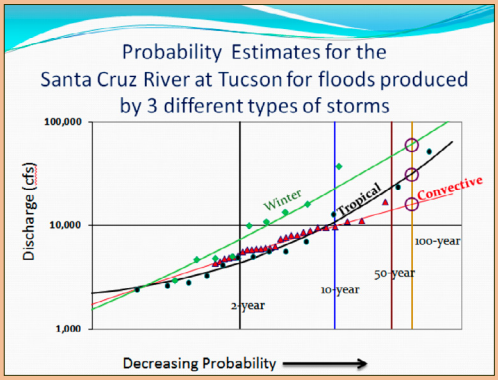
Leveraged Funding Sources: NOAA-Sectoral Applications Research Program (*Primary Funder*), IAI-Global Change Research Program, U.S.-Mexico Transboundary Aquifer Assessment Program, UA Water Resources Research Center

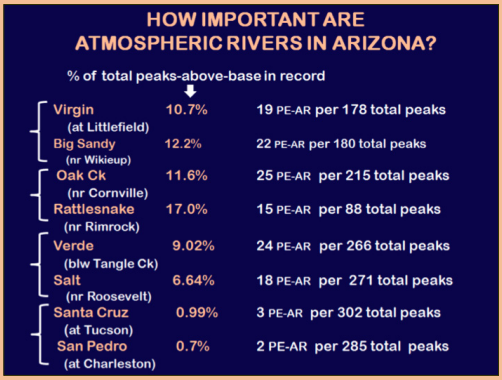
Hydroclimatology and Paleohydrology for Decision Support

CLIMAS Investigators: K. Hirschboeck, G. Garfin, K. Sammler, D. Zamora-Reyes, and S. Kim

Other Collaborators: A. Coles (Univ. of Arizona); J. Kennedy and N. Paretti (U.S. Geological Survey); J. Jones (California Dept. of Water Resources); R. Quay (Arizona State Univ.); D. Toy (City of Chandler); B. Cosson (Arizona Dept. of Water Resources)

Partners: Multiagency Task Force of the Arizona Flood Warning System





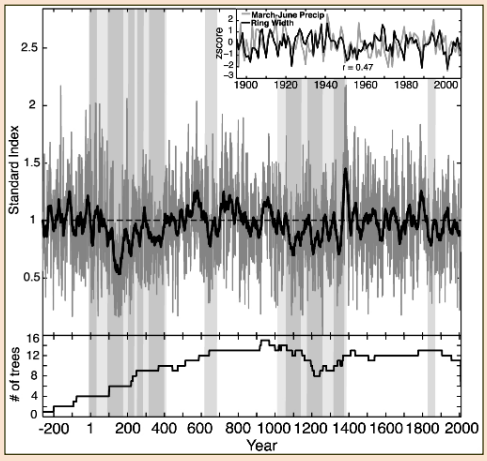
Preliminary findings show that "pineapple express/atmospheric river" (PE-AR) storms are only one of several types of winter storms that lead to flooding in Arizona. There are large geographic differences in their importance.

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.

Findings: For several Arizona streams, we determined flood recurrence intervals for individual components of mixed flood populations (floods produced by different kinds of storms). Mixed population analysis is used to make realistic, probability-based projections of future flooding in Arizona under different scenarios of climate change.

We also explored "pineapple express/atmospheric river" (PE-AR) storms that produce nearly all major winter floods in California. We used our flood hydroclimatology database to see if this type of storm is similarly dominant as the cause of most major winter floods in Arizona. Our preliminary findings show that these storms are only one of several types of winter storms that lead to flooding in Arizona and that there are large geographic differences in their importance. PE-ARs were responsible for more floods in central and northern Arizona than in southern Arizona, especially in the relatively small watershed that drains the Mogollon Rim.

Leveraged Funding Sources: USGS Arizona Science Center



Summitville bristlecone chronology standard index (grey) smoothed with a 25-yr moving average (black) and number of trees (bottom). Narrow shaded bars are the 10 driest 25-yr periods defined by the Summitville chronology. Wide shaded bars highlight multicentury periods of increased aridity and drought frequency. Upper right inset: ring width (black) with March-July PRISM precipitation data from Rio Grande headwaters hydrologic unit (grey).

Patterns and Causes of Southwest Drought Variability

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

Other Collaborators: T. Ault (National Center for Atmospheric Research); B. Udall (Western Water Assessment); J. Cole and D. Meko (Univ. of Arizona)

Partners: Intergovernmental Panel on Climate Change, U.S. Bureau of Reclamation, U.S. Dept. of Defense, 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.

Findings: A new 2200-yr long tree-ring record from southern Colorado suggests that medieval period megadroughts, well-documented in a number of different paleoclimatic records, are not unique. A megadrought in the 2nd century likely matched the severity of medieval droughts in the Southwest, and may have had similar causes.

Deliverables: *Publications* – Routson et al. 2011. Second century megadrought in the Rio Grande headwaters, Colorado: How unusual was medieval drought? *Geophysical Research Letters* 38, L22703, doi:10.1029/2011GL050015.

Ault et al. 2012. The continuum of drought variability in western North America: insights from instrumental, paleoclimate and global climate model data. *Journal of Climate*. (In review)

Leveraged Funding Sources: National Science Foundation, NOAA-C2D2

Paleo-Southwest Monsoon Dynamics

CLIMAS Investigators: J. Overpeck, D. Ferguson, and S. Truebe

Other Collaborators: J. Cole (Univ. 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. Researchers are discussing the feasibility of carrying out a stakeholder-driven assessment of paleoclimatic field sampling of cave formations.

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

Communicating Science


December 20, 2011

Southwest Climate Outlook

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In this issue...

Feature Article pg 3

Atmospheric rivers (ARs) deliver torrential precipitation that causes punishing floods. Some ARs, such as the Pineapple Express, strike Arizona in the winter, and initial research suggests climate change will intensify these events, in addition to other alterations.

Recent Precipitation pg 6

In the past 30 days, several moist and cold early winter storms delivered copious rain and snow, and many parts of the Southwest have experienced more than 150 percent of average precipitation.

El Niño Status and Forecast pg 16

A weak La Niña event continues and forecasts suggest a high probability that either a weak or moderate event will persist through April.

Credit: Walter Freeman

Winter storms often blanket Arizona and New Mexico mountains with snow. In late November and early December, several storms dumped copious precipitation across the Southwest.

Would you like to have your favorite photograph featured on the cover of the Southwest Climate Outlook? For consideration send a photo representing Southwest climate and a detailed caption to: zguido@email.arizona.edu

CLIMAS ARIZONA COOPERATIVE EXTENSION ARIZONA NM STATE UNIVERSITY

The information in this issue is available on the Web: http://climas.arizona.edu/outlooks/swco

The Southwest Climate Outlook

CLIMAS Investigators: Z. Guido, G. Garfin, M. Crimmins, G. Owen, and J. Swetish

Other Collaborators: N. Selover (Arizona State Climatologist); S. Doster (Univ. of Arizona)

Abstract: *The Southwest Climate Outlook* (SWCO) summarizes climate and weather information from disparate sources, providing more than 1,700 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.

Deliverables: *Publications* – 12 issues published in both pdf and html formats
http://www.climas.arizona.edu/outlooks/swco

La Niña Drought Tracker/Monsoon Tracker

CLIMAS Investigators: Z. Guido, G. Garfin, M. Crimmins, and J. Swetish

Abstract: One of the strongest La Niña events in the last 60 years occurred in August 2010, persisting for two consecutive winters, signaling that the Southwest U.S. was likely to experience below average precipitation during the winters. These events provided a good opportunity to develop a regional climate service that informed the U.S. Southwest of the evolving drought conditions and the underlying climate connections. *La Niña Drought Tracker* is a two-page document published each month between December 2011 and April 2012, when La Niña impacts were most heavily experienced in the Southwest. It was disseminated to more than 1,700 subscribers and routinely viewed by more than 300 resource managers and decision makers each month, in addition to numerous media sources. The success of the *Drought Tracker* led to the development of the *Southwest Monsoon Tracker*. The *Monsoon Tracker* was published from June-October 2011, helping the region stay abreast of the latest science, impacts, and expert insights about climate and the monsoon.

Findings: The *Drought Tracker* was evaluated after its first season of publication. Results suggest that: 1) it improved readers' understandings of climate and drought and 2) it helped readers better prepare for developing drought conditions.

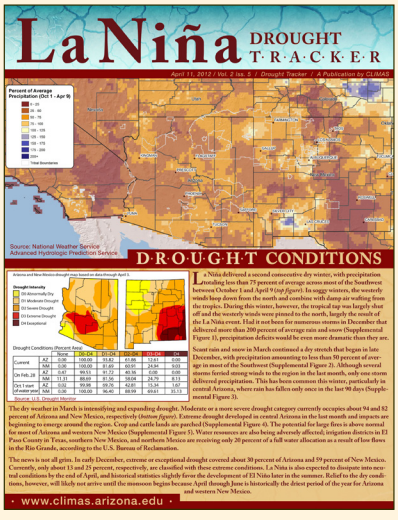
Deliverables: *Publications* – Guido et al. 2012. Informing decisions with a climate synthesis product: Implications for regional climate services. *Weather, Climate, and Society*. (In review)

Five issues of La Niña Drought Tracker published: http://www.climas.arizona.edu/outlooks/drought-tracker

Five issues of the Monsoon Tracker published: http://www.climas.arizona.edu/outlooks/monsoon-tracker

Presentations – *Regional Climate Services: Taking advantage of climate events to inform decisions*. 19th Conference on Applied Climatology, American Meteorological Service, 18–20 July 2011, Asheville, NC.

Climate Services: A CLIMAS/RISA Perspective. Presentation at the 6th Southwest Hydrometerology Symposium, September 27-28, 2011, Arizona State University, Phoenix, AZ.


La Niña DROUGHT TRACKER

April 11, 2012 / Vol. 2 Iss. 5 / Drought Tracker / A Publication by CLIMAS

Source: National Weather Service Advanced Hydrologic Prediction Service

DROUGHT CONDITIONS

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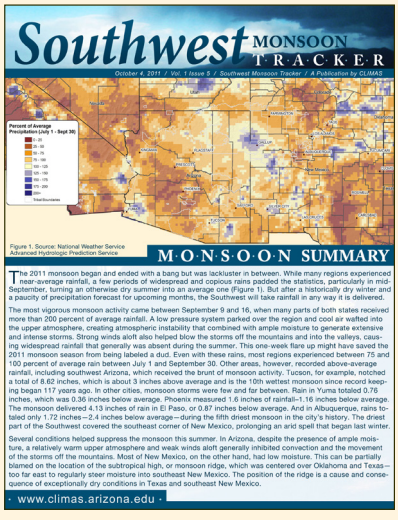
Southwest MONSOON TRACKER

October 4, 2011 / Vol. 1 Issue 5 / Southwest Monsoon Tracker / A Publication by CLIMAS

Figure 1. Source: National Weather Service Advanced Hydrologic Prediction Service

MONSOON SUMMARY

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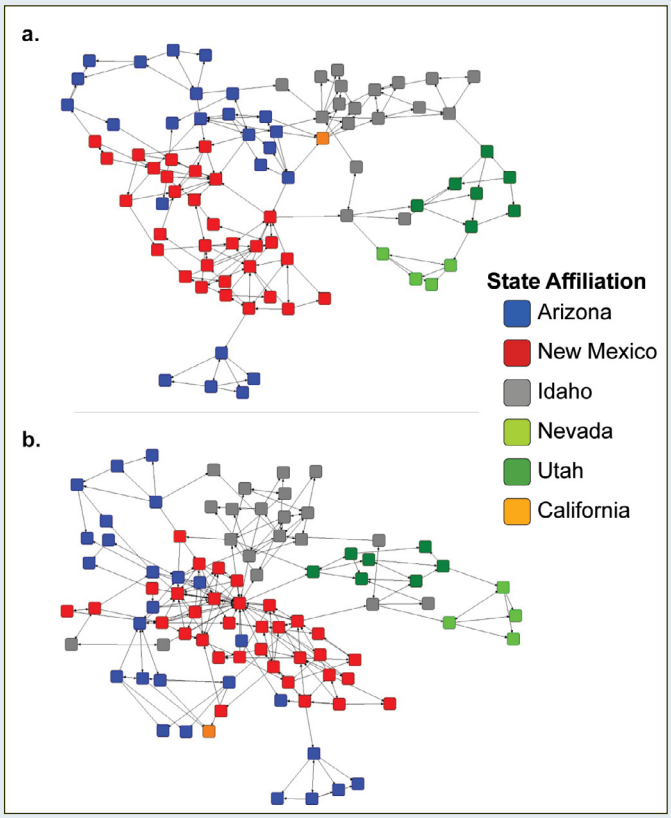
Evaluation of Fire Forecast Products to Enhance U.S. Drought Preparedness and Response



a) By hypothetically removing the two Predictive Services meteorologists, the overall "connectivity" of the network diminishes, and geographic divisions become more pronounced. The network centrality with the two Predictive Services meteorologists is 10.97%; without them, the network centrality drops to 3.41%. b) While members of the network are somewhat grouped by state, much interaction happens across state boundaries, suggesting that geographic location is not a determining factor in the frequency of interaction between fire management professionals.

CLIMAS Investigators: G. Owen, D. Ferguson, and J. McLeod

Other Collaborators: T. Brown (Desert Research Institute); C. Kolden (Univ. of Idaho)

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

Abstract: This project: 1) assessed 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.; 2) evaluated how these products are used; and 3) analyzed network patterns across regional and federal networks of fire management to see how information is communicated across agencies.

Findings: Our social network analysis demonstrates that Predictive Services meteorologists occupy vital positions in the Southwest's fire management network in terms of information production, distribution, and communication.

Deliverables: *Publication* – Owen et al. 2012. Wildfire Management and Forecasting Fire Potential: The Roles of Climate Information and Social Networks in the Southwest U.S. *Weather Climate and Society*. (In Review)

Presentations – *Assessing Climate Services in Wildland Fire Management - A Social Network Analysis of the Southwest*. 19th Conference on Applied Climatology, American Meteorological Service, July 18-20, 2011, Asheville, NC.

Wildfire Management and Forecasting Fire Potential: The Roles of Climatology, Perceptions, and Social Networks in the Southwest U.S. 3rd Human Dimensions of Wildland Fire Conference, April 16-20, 2012, Seattle, WA.

Results communicated to members of National Interagency Fire Center and Predictive Services and to wildfire management practitioners.

Leveraged Funding Sources: NIDIS Coping with Drought 2009-2010

Forecast Evaluation and Application Research

CLIMAS Investigators: H. Hartmann and B. Colby

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

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

Abstract: Early in the CLIMAS program's history, dialogue with stakeholders clearly identified significant barriers precluding more extensive and effective use of hydroclimatic forecasts. 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 also examine the impacts of misinterpretation of forecast products. With CPC, we collaboratively developed the new Dynamic Probability of Exceedance Climate Outlook product, which allows users to consider any probability or climate variable threshold rather than the standard terciles that users find frustrating. The interactive Dynamic POE tool supports engagement with decision makers about any probability threshold (e.g., 5% risk) or past extremes. We are also supporting CPC's development of their Verification Web Tool, a corollary to the Forecast Evaluation Tool, which represents CPC efforts to develop internal skills in web application development.

Deliverables: *Publication* – Mealy et al. 2012. Economic implications of climate forecast skill for water supply managers. *Weather, Climate and Society*. (In Prep)

Presentation – *Using seasonal outlooks*. Drought Webinar Series. Southern Climate Impacts Planning Program, January 12, 2012.

Understanding and Communicating Climate Change in the Southwest

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

Partners: Arizona Dept. of Environmental Quality, Univ. of Arizona-Institute of the Environment, Western Water Assessment, California Nevada Applications Program, NOAA-Earth Systems Research Laboratory, Univ. Corporation for Atmospheric Research, National Judicial Law College, Univ. of Arizona College of Law

Abstract: The goals of this project are to: 1) lead efforts to communicate about climate variability and change to decision and policy makers in the Southwest; and 2) make climate knowledge useful for stakeholder understanding and decision making.

Deliverables: *Publications* – entries on the SW Climate Blog: http://www.southwestclimatechange.org

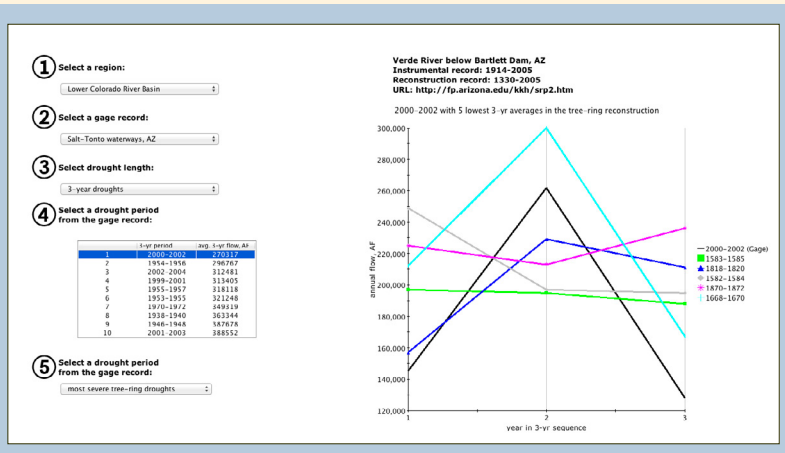
Decision Support Tools: CLIDDSS, FET, Paleo Toolkit and Others

CLIMAS Investigators: H. Hartmann, G. Garfin, C. Woodhouse, and K. Morino

Other Collaborators: S. Srinivasin, D. Hammond, and D. Martinez (Univ. 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

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.



Paleo Toolkit: Example of Sequence of Years

Deliverables: *Websites and Webtools* – 1) Carpe Diem West Academy Website. Website providing decision support for management of water resources under climate variability and change. http://carpediemwestacademy.org

2) Dynamic Probability of Exceedance Webtool. A user-controlled seasonal climate outlook product that allows users to customize the probabilistic seasonal climate forecast. http://www.ua-alic.com/DynamicPOE

3) Paleo Toolkit: Drought Analog Visualization Tool finds analogs of droughts in the instrumental record with those from paleostreamflow reconstructions. Gage Variability Tool visualizes streamflow observations in the context of frequency percentiles defined by paleostreamflow reconstructions. http://erebor.arid.arizona.edu/PaleoToolKit

4) Climate Information Delivery and Decision Support System (CLIDDSS). CLIDDSS is now ready for testing by users and providers. http://cliddss.arid.arizona.edu/CLIDDSSClient

5) Online Interactive Forecast Evaluation Tool. http://fet.hwr.Arizona.edu/ForecastEvaluationTool

Training – Adaptation and Mitigation and NWS Decision Support. Advanced Operational Climate Services Residential Training Course. National Weather Service, November 17, 2011, Boulder, CO. (Training for 35 NWS personnel from across the U.S.)

Publication – O'Lenic et al. 2011. An emerging protocol for research-to-operations (R2O) at CPC. In: *Climate Prediction S&T Digest*, Science and Technology Infusion Climate Bulletin Supplement, National Weather Service, Silver Spring, MD.

Leveraged Funding Sources: Carpe Diem West

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

CLIMAS Investigators: C. Woodhouse, K. Hirschboeck, H. Hartmann, D. Griffin, and K. Morino

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

Partners: Salt River Project

Abstract: 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 powerpoint presentations).

Deliverables: *Webtools* – The paleotool component of Treeflow, under development since 2008, was mostly completed this year, though it is still undergoing beta testing. http://treeflow.info/toolbox.html

Workshop – Tree-Ring Monsoon Workshop for Water Managers. Hosted by Salt River Project, Phoenix, AZ, Nov 11, 2011. http://monsoon.ltrr.arizona.edu/documents.html

Leveraged Funding Sources: NIDIS Coping with Drought 2009-2010

Links with NOAA

Many of our projects engage NOAA entities and NOAA regional partners. The project described here exemplifies these types of links:

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, NOAA-National Weather Service, NOAA-Regional Climate Centers, State Climatologists, Carpe Diem West, NWS Climate Services Division

Abstract: Over the past several years, discussion about the design and implementation of national climate services has increased. 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. The substantial increase in the national discussion about national climate services increasingly involves CLIMAS investigators, in areas ranging from understanding stakeholder needs for climate services to effectively transitioning research to operations.

Deliverables: *Publications* – National Research Council. 2012. *The National Weather Service Modernization and Associated Restructuring: A Retrospective Assessment*. Committee on the Assessment of the National Weather Service's Modernization Program, National Academy Press, Washington, D.C., 108pp. (Hartmann is a co-author)

Policy Statement Writing Team. 2012. *Draft AMS Policy Statement on Climate Services*. (In review. Hartmann is a co-author)

National/North American Seasonal Assessment Workshops

CLIMAS Investigators: G. Garfin

Other Collaborators: D. Zierden (Southeast Climate Consortium); T. Brown and 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); E. Delgado, C. Leonard, J. Sullens, and I. Hirschfield (Natl. Interagency Coordination Center-Predictive Services); D. O'Brien (Northwest Coordination Center); 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.

Findings: With regard to the use of videoconferencing for convening the workshop in 2011 and 2012—which was a departure from the 2003-2010 NSAW convention of convening in-person workshops—participants found that videoconferencing reduced opportunities for informal interactions that are important for professional development, exchange of ideas, and interactions with climate forecasters.

Deliverables: *Publications* – Report to NICC Predictive Services on GACC preferences regarding videoconferencing. An abbreviated version of this report was delivered to NICC Predictive Services in April 2011.

National Seasonal Assessment Workshop for the Eastern, Southern & Southwest Geographic Areas Report, January 2012
http://www.predictiveservices.nifc.gov/outlooks/2012_ESAW_Report.pdf

North American Seasonal Assessment Workshop/National Seasonal Assessment Workshop for the Western States and Alaska Report, April 2012

Leveraged Funding Sources: National Interagency Fire Center

Drought

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

CLIMAS Investigators: A. Meadow, M. Crimmins, and 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 evaluated the development of AZ Drought Watch to determine whether revisions to the project could increase the use and usefulness of this decision-making tool.

Findings: We found several weaknesses in the public-participation reporting system model. Participation was reduced due to participants' overcommitment and time constraints, consultation fatigue, and confusion about the value or qualitative impact reports. These findings lead us to conclude that relying on citizen participation for data as complex and inscrutable as drought impacts is not the most effective approach. In the case of drought impacts monitoring, the task should be delegated to professional resource managers who are intimately familiar with a particular region, monitor the same areas on a regular basis, and are equipped with the specialized knowledge to discern drought impacts.

Deliverables: *Publication* – Meadow, et al. 2012. Field of Dreams or Dream Team: Assessing Two Models of Drought Impact Reporting in the Semi-Arid Southwest. *Bulletin of the American Meteorological Society*. (In review)

Leveraged Funding Sources: National Drought Mitigation Center

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

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

Other Collaborators: S. Marsh, W. Van Leeuwen, and B. Orr (Univ. of Arizona, Arizona Remote Sensing Center); K. Cozzetto, J. Nania, and S. Duren (Western Water Assessment)

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. 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 aim to help these two communities reduce their vulnerability to drought, cope with unavoidable drought impacts, and plan for long-term sustainability in the region.

Findings: Recent acute drought conditions across the Four Corners have emerged through a combination of mounting deficits in both the winter and summer precipitation seasons. The period has been characterized by rapid transitions between extreme, short-term wet periods punctuating persistent, long-term drought conditions. This has led to a complicated set of impacts from reductions in water resources to damage from extreme precipitation and flooding events with summer storms. Interviews and discussion groups with resource management staff at Hopi have identified that a sophisticated and extensive data stream related to drought is being collected by managers and technicians across divisions, but is not being utilized to its fullest extent for drought monitoring and policy decisions. An effort to streamline this process through a standardized drought monitoring instrument is underway.

Deliverables: *Workshops* – Two workshops with Hopi Dept. of Natural Resources (May and December 2011).

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, G. Garfin, and A. Meadow

Partners: Hopi Dept. of Natural Resources-Office of Rangeland Management, Navajo Water Resources Program

Abstract: This project uses a collection of 15 tree-ring chronologies surrounding the Navajo and Hopi tribal lands in the Four Corners region to reconstruct climate history. We identify and characterize multiyear droughts, investigate drought seasonality, and frame the ongoing 21st century drought in the context of the past four centuries. Historical research is used to assess the socioeconomic circumstances that coincided with notable periods of persistent drought and wetness on the tribal lands. The results from this project will be published in a peer-reviewed journal and used to generate a set of outreach materials, both in the form of a brief report written for a general audience and a presentation for tribal members.

Findings: The instrumental record does not adequately represent the full range of natural climatic variability on the tribal lands. Pre-instrumental drought events have far exceeded anything witnessed by the Four Corners region in the modern era. Many of the historically significant droughts of the past (e.g., 17th century Puebloan Drought) were not merely winter phenomena, but persisted through the summer season as well.

Deliverables: *Publications* – Faulstich, H. 2012. *Reconstructed cool- and warm-season precipitation over the tribal lands of northeastern Arizona*. Master's Thesis. School of Geography and Development, Univ. of Arizona.

Faulstich et al. 2012. Reconstructed cool- and warm-season precipitation over the tribal lands of northeastern Arizona. *Climatic Change*. (Submitted)

Presentation – Project presented to Hopi Dept. of Natural Resources in May 2011.

Leveraged Funding Sources: National Science Foundation

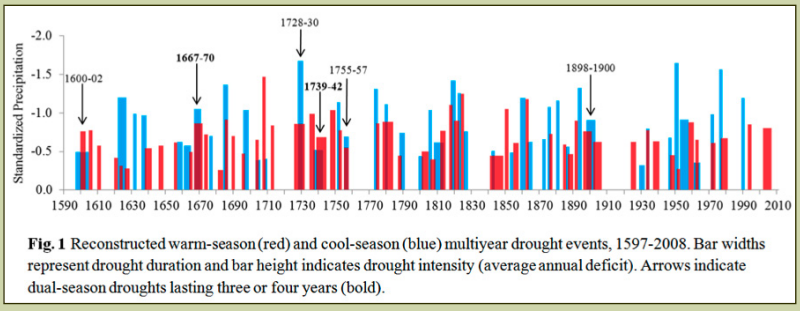


Fig. 1 Reconstructed warm-season (red) and cool-season (blue) multiyear drought events, 1597-2008. Bar widths represent drought duration and bar height indicates drought intensity (average annual deficit). Arrows indicate dual-season droughts lasting three or four years (bold).

The instrumental record does not adequately represent the full range of natural climatic variability possible on the tribal lands. Pre-instrumental drought events have far exceeded anything witnessed by the Four Corners region in the modern era.

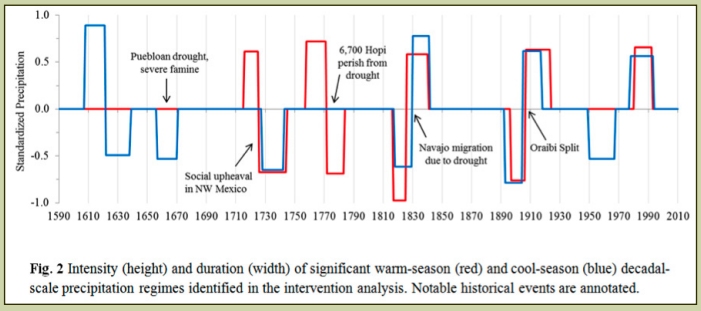


Fig. 2 Intensity (height) and duration (width) of significant warm-season (red) and cool-season (blue) decadal-scale precipitation regimes identified in the intervention analysis. Notable historical events are annotated.

Many of the historically significant droughts of the past (e.g. 17th century Puebloan Drought) were not merely winter phenomena, but persisted through the summer season as well. This type of drought (winter deficits followed by a failed monsoon) can have devastating consequences on the tribal lands.

Economics & Livelihoods

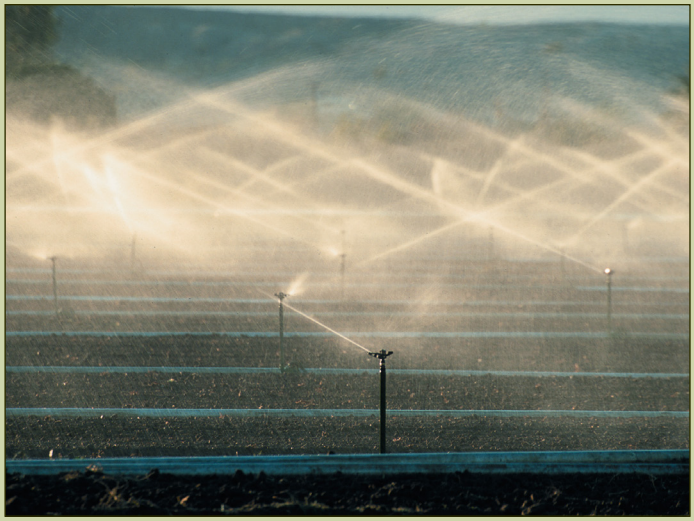
Sectoral Impacts of Drought and Climate Change

CLIMAS Investigators: G. Frisvold

Other Collaborators: K. Konyar (California State Univ. San Bernardino); S. Ponnaluru (Washington State Univ.); S. Hecht (Univ. of California Los Angeles)

Partners: National Parks Conservation Association, Bureau of Reclamation, Central Arizona Project

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.



Yuma Irrigation Photo credit: George Frisvold

Findings: Significant reductions in water availability (up to 25%) for irrigation in Southwestern states impose relatively modest costs to the region's crop producers, based on simulations from the US Agricultural Resource Model (USARM). The simulated acreage and water use responses do not imply large, implicit transfers from water surplus sub-regions to water deficit sub-regions. Higher crop prices from reduced production imposed direct losses of $130 million on first purchasers of crops, which include livestock and dairy producers, and cotton gins.

Deliverables: *Publications* – Frisvold, G. and K. Konyar. 2012. Less Water - How Will Agriculture in Southern Mountain States Adapt? *Water Resources Research* 011WR011057RR. (In press)

Hecht, S. and G. Frisvold. 2012. *Warming to Climate Change: Adaptation in Places on the Edge*. In C. Bauer and L. Gunderson (eds.) Tucson: Univ. of Arizona Press. (Submitted)

Frisvold, G., X. Ma, and S. Ponnaluru. 2012. Climate Change and Southwestern National Parks: Effects on Visitor Demand and Local Economies. *Climatic Change*. (In review)

Climate Change Mitigation Strategies and Policies

CLIMAS Investigators: G. Frisvold

Other Collaborators: A. Barnhart and W. Ela (Univ. of Arizona)

Partners: Tucson Water, Navajo Nation, Bureau of Reclamation

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, particularly through adoption of renewable energy technologies.

Findings: An analysis of the economic efficiency of an initial prototype solar desalination system shows that if users were only required to pay to recover the operation, maintenance, and replacement (OM&R) of the prototype system, the costs would range from $1.97 - $2.07 per 100 gallons depending on the brine disposal method. Estimated OM&R costs per 100 gallons for the prototype are lower than rates paid by water haulers in the region.

Deliverables: *Presentation* – Results presented at 56th Annual New Mexico Water Conference, sponsored by the US Bureau of Reclamation and the New Mexico Water Resources Research Institute. December 13-14, 2011. Alamogordo, NM.

Leveraged Funding Sources: Bureau of Reclamation; Arizona Technology Research Initiative Fund

Health

Climate and Health

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

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

Partners: Santa Cruz County Health Dept., Arizona Dept. of Health Services

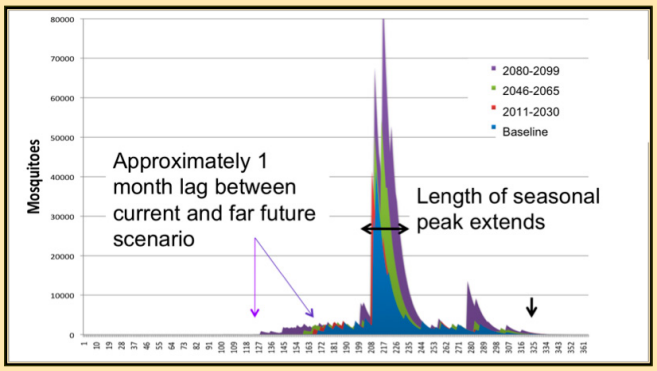
Abstract: Climate change and variability can strongly control the population dynamics of disease vectors such as mosquitoes, altering their location and seasonality and possibly increasing the risk of disease transmission to humans. This project develops and implements a climate-based Dynamic Mosquito 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.

Findings: 1) Both the *Ae. aegypti* (dengue vector) and *Cx. quinquefasciatus* (West Nile vector) models indicate a lengthening of the mosquito season and thus increased risk of disease transmission under climate change scenarios. These changes, however, are regional and highly dependent on the seasonality of rainfall.

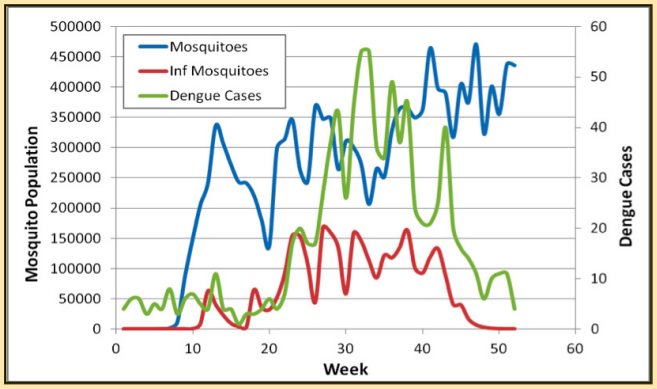
2) Although vector populations are a key component of disease transmission, inclusion of the viral pathogen into the models creates a better understanding of the disease ecology. Many environments are capable of maintaining a stable vector population but cannot sustain viral transmission. We can assess not only if mosquitoes are changing in abundance, but if some of them can also carry the disease and transmit it.

Deliverables: *Model* – The *Ae. aegypti* model with dengue virus component is nearing completion with several components including the effects of daily temperature cycles on gonotrophic and viral development, age dependent mortality, non-linear life histories, and a dynamic SEIR model which allows feedbacks between mosquito and human infection rates.

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



Potential change in Aedes aegypti *(dengue vector) season length in Nogales, AZ using downscaled GCM scenarios.*



Inclusion of the viral pathogens in the models helps researchers distinguish infected mosquitoes – this is a key new strength. Researchers can assess not only if mosquitoes are changing in abundance, but if some of them can also carry the disease and transmit it.

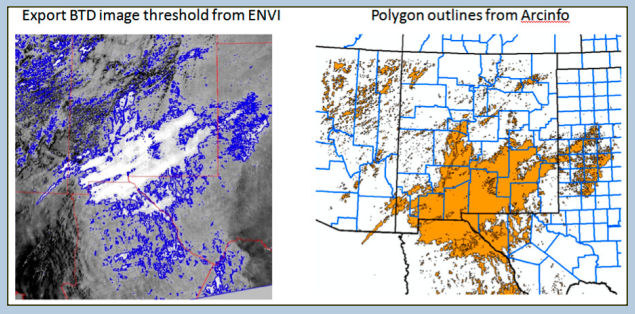
Air Quality and Climate

CLIMAS Investigators: D. DuBois

Other Collaborators: M. Bean, R. Armenta, E. Smith, R. St. Hilaire, S. Sanogo, M. Bleiweiss, S. Engle, C. Runyon, S. Brown, and K. Wiberg (New Mexico State Univ.); R. Fitzgerald and T. Gill (Univ. of Texas El Paso); M. Green, D. Koracin, and R. Vellore (Desert Research Institute); M. Pitchford (NOAA Special Operations & Research Division; Environmental Protection Agency-Office of Air Quality); I. Kavouras (Univ. of Arkansas); J. Flores Margez (Univ. Autonoma de Ciudad Juarez); M. Baca (New Mexico Environment Dept.–Air Quality Bureau)

Partners: New Mexico State Univ.-Cooperative Extension, New Mexico Environment Dept.-Air Quality Bureau, New Mexico Dept. of Health-Border Health, NOAA-NWS Albuquerque, Santa Teresa, and El Paso Weather Forecast Offices, The Joint Advisory Committee for the Improvement of Air Quality in the Paso del Norte, U.S. Environmental Protection Agency Region 6, Texas Commission on Environmental Quality, Procuraduría Federal de Protección al Ambiente, Gobierno del Estado de Chihuahua, Gobierno Municipal de Ciudad Juarez, Border Partners, U.S. Army Research Laboratory-White Sands Missile Range, Secretaría de Medio Ambiente y Recursos Naturales

Abstract: This project investigates the connections between air quality, climate, and air mass transport patterns by tracking the frequen-



Researchers developed a tool to extract regional dust events based on satellite imagery. The tool processes raw images and outputs to an ArcGIS layer.

cies, intensities, and locations of dust storms and wildfires over time. Additionally, researchers are supplying 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.

Deliverables: *Tools* – Community data portal using the UNIDATA Thematic Real-time Environmental Distributed Data Services (THREDDS) and Repository for Archiving, Managing and Accessing Diverse Data (RAMADDA) server applications. This portal makes public data sets available that have been archived at NMSU, the Center for Applied Remote Sensing in Agriculture, Meteorology and Environment (CARSAME), and New Mexico Climate Center. THREDDS: http://cirrus.nmsu.edu:8080/thredds. RAMADDA: http://cirrus:8080/repository.

We created a tool to extract regional dust events based on satellite imagery. MODIS and AVHRR images from 2009–present have been processed using this tool, which will be available on the UNIDATA community portal.

Publication – Koracin et al. 2011. Regional source identification using Lagrangian stochastic particle dispersion and HYSPLIT backward-trajectory models. *Journal of the Air & Waste Management Association* 61(6): 660-672.

Presentations – Dust Plume Identification for Human Exposure of Regional Dust Events Using Remote Sensing. *Third Symposium on Environment and Health and the 92nd Annual Meeting of the American Meteorological Society*. January 25, 2012, New Orleans, LA.

Sunland Park Low-Wind Exceedances PM2.5 Study. *Presented at the Air & Waste Management Association's 104th Annual Conference & Exhibition*, June 23, 2011, Orlando, FL.

An analysis of 20 years of aerosol and visibility data in the Lake Tahoe Basin. *Presented at the Air & Waste Management Association's 104th Annual Conference & Exhibition*, June 23, 2011, Orlando, FL.

Leveraged Funding Sources: New Mexico Dept. of Health-Border Health; Office of the New Mexico State Climatologist; New Mexico State Univ. College of Agricultural, Consumer, and Environmental Science; U.S. Environmental Protection Agency Border 2012; UCAR-UNIDATA; American Association of State Climatologists

CLIMAS Contributions to the National Climate Assessment

During the current reporting period many members of the CLIMAS team made substantial contributions to the National Climate Assessment both in terms of funded projects and as volunteer authors, editors, and reviewers. The CLIMAS program is committed to making future contributions to the National Assessment process, though the level of committment will of necessity be directly related to our ability to secure funds for that work.

Assessment of Climate Change in the Southwest United States: A technical report prepared for the U.S. National Climate Assessment

CLIMAS Investigators: G. Garfin, A. Comrie, M. Crimmins, D. Ferguson, G. Frisvold, H. Hartmann, J. Overpeck, M. Wilder, J. Galayda, A. Jardine, and C. Greene

Other Collaborators: D. Liverman (Univ. of Arizona)

Partners: Western Water Assessment, California Nevada Applications Project, NOAA-Earth Systems Research Laboratory, Dept. of Interior SW Climate Science Center, 60+ authors and reviewers

Abstract: This report is a summary and synthesis of the past, present, and projected future of the region's climate, examining what this means for the health and well-being of human populations and the environment throughout six Southwestern states, an area that includes vast stretches of coastline, an international border, and the jurisdictions of more than one hundred Native nations. The report looks at climate and its effects on scales ranging from states to watersheds and across ecosystems and regions; at links between climate and resource supply and demand, and between the costs and benefits to secure food, water, energy, and material goods for the region's inhabitants; and at the vulnerabilities climate imposes for all facets of the region, and the responses, or adaptations, this forces society to create. Stakeholders have been actively engaged in defining the scope of this report and in reviewing the document. Written chiefly during late 2011 with revisions in early 2012, this assessment provides a snapshot of the current state of climate change knowledge related to the region.

Deliverables: *Publication* – Garfin, et al. 2012. Assessment of Climate Change in the Southwest United States: a Technical Report Prepared for the U.S. National Climate Assessment. *Technical Input to the National Climate Assessment*. Draft submitted on March 1, 2012.

Meetings – Prospective Authors Workshop. Sponsored by Southwest Climate Alliance. August 1-4, 2011, Boulder, CO. G. Garfin – lead organizer.

Coordinating Lead Authors Meeting. Sponsored by Southwest Climate Alliance. January 9-11, 2012, Scripps Institute of Oceanography, San Diego, CA.

Leveraged Funding Sources: U.S. Geological Survey; National Aeronautics and Space Administration

Assessing Regional Climate Service Needs Through Cooperative Extension

CLIMAS Investigators: M. Crimmins, J. Brugger, and D. DuBois

Partners: Arizona Cooperative Extension, New Mexico Cooperative Extension

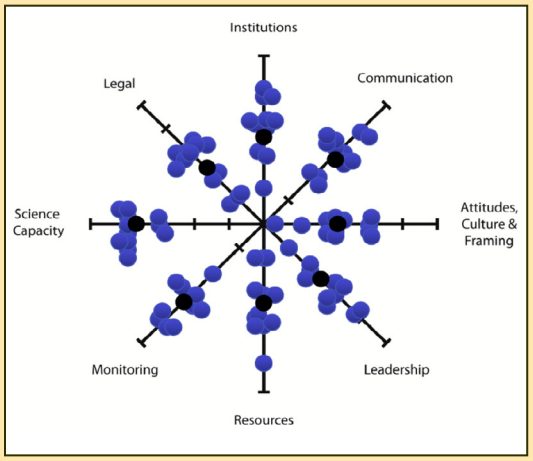
Abstract: Cooperative Extension (CE) has over 100 years of experience in delivering science-based decision support to clientele from multiple sectors. The CE structure enables a high level of connectedness and awareness of local issues and provides opportunities to assess local and multi-sector climate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

Findings: Participants in the study displayed a high awareness of current, past, and projected weather and climate conditions. They used a variety of weather and climate information sources and many had their own rain gauges or weather stations at home. Short-term drought impacts ranchers more than any other group because of its effects on vegetation and water sources for cattle. Drought also has extreme impact on forest health and fire danger. Farmers feel they are impacted by perceived recent changes in climate variability and in the frequency of extreme events like hot and cold temperature extremes, wind events and shifts in growing season length.

Deliverables: Publications – Brugger, J. and M. Crimmins. 2012. *Weather, Climate and Rural Arizona: Insights and Assessment Strategies*. Report for the National Climate Assessment. Submitted on March 1, 2012.

Brugger, J., M. Crimmins, and G. Owen. 2011. Finding a place for climate science in the rural West. *Rural Connections* 5: 5-10.

Leveraged Funding Source: National Climate Assessment



Workshop participants constructed "spider diagrams" to evaluate current assessment capacity in the Colorado River Basin. The highest assessment capabilities were in science capacity and environmental monitoring.

The lowest assessment capabilities were in leadership and attitudes (i.e., attitudes toward climate change inhibit development of capacity for assessment and capacity to adapt to climate changes).

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

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

Other Collaborators: K. Redmond and T. Wall (California Nevada Applications Program); E. Gordon (Western Water Assessment); A. Waple (NOAA-National Climatic Data Center); T. Iseman (Western Governors' Association); E. Martin (Univ. of Arizona Cooperative Extension); M. Walsh (United States Dept. of Agriculture); S. Moser (Susanne Moser Research & Consulting); N. Chhetri (Arizona State Univ.); J. Smith (Stratus Consulting); L. Dilling (Univ. 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, convened a workshop (June 2011) 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 focused on water as the major medium through which climate change impacts will manifest in the CRB, and looked broadly at adaptation strategies in relation to agricultural, water management, and ecosystem management sectors. 68 participants attended the workshop, including 55 stakeholders.

Findings: To build capacity for ongoing assessment in the Colorado River Basin, workshop participants recommended: a) implementation of pilot projects to build partnerships across sectors and disciplines; b) development of learning networks and communities of practice where data and information can be shared; and c) allocating resources to science translation, education, and outreach. Participants determined that the highest assessment capabilities were in scientific expertise and environmental monitoring. The lowest assessment capabilities were in leadership and attitudes (e.g., attitudes toward climate change inhibit development of capacity for assessment and capacity to adapt to climate changes).

Deliverables: Workshop – Evaluating Our Capacity: A Discussion of Capability for Ongoing Climate Assessment in the Colorado River Basin. June 6-8, 2011, Boulder, CO.

Publications – Wall, T., G. Garfin, and J. Galayda. 2012. *Evaluating Our Capacity: A Discussion of Capability for Ongoing Climate Assessment in the Colorado River Basin*. Workshop Report, June 6-8, 2011, Boulder, CO. Tucson, AZ: CLIMAS, 11pp. http://www.climas.arizona.edu/files/climas/pubs/crb-workshop-report-2011.pdf (Information communicated to workshop participants.)

Garfin, G. and J. Galayda. 2011. *Evaluating our Capacity: Assessment White Paper.* Tucson, AZ: CLIMAS, 31pp. http://www.climas.arizona.edu/files/climas/workshops/06-06-11/assessment-and-adaptation-white-paper-june-1-2011-1.pdf

Climate Mitigation and Agriculture: Public Policy Education

CLIMAS Investigators: G. Frisvold, Z. Mirza, and X. Vu

Other Collaborators: D. Fort (Univ. of New Mexico, School of Law); 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.

Findings: The project assessed the economic impacts of climate change legislation, the American Clean Energy and Security Act of 2009 (H.R. 2454) on New Mexico agriculture. The proposed legislation entails a rise in energy and fertilizer costs. By 2020, energy costs are projected to rise 4-13% and fertilizer costs by 0.3-2%. We estimate that New Mexico net farm income rises by about 4.1% in 2020 because of the legislation. Not all agricultural producers would gain however. Crop producers experience improved revenues from higher crop prices, largely because carbon sequestration incentives would encourage retirement of cropland for tree planting in other parts of the country. Traditional ranchers, the dominant practice throughout this region, will face higher feed costs with limited opportunity to participate in carbon-offset markets.

Deliverables: *Publication* – Hurd et al. 2011. Estimated Impacts of Climate Change Legislation on New Mexico Agriculture. *Bulletin 801, Agricultural Experiment Station.* College of Agricultural, Consumer and Environmental Sciences. Las Cruces: New Mexico State Univ.

Leveraged Funding Source: National Climate Assessment; Cotton Incorporated; New Mexico's Experimental Program to Stimulate Competitive Research (funded by National Science Foundation)

Publications

Bark, R., D. Osgood, B. Colby, and E. Halper. 2011. How Do Homebuyers Value Different Types of Green Space? *Journal of Agricultural and Resource Economics* 36(2): 395–415.*

Brugger, J. and M. Crimmins. 2012. Weather, Climate and Rural Arizona: Insights and Assessment Strategies. *Technical Input to the National Climate Assessment.* Submitted on March 1, 2012.

Brugger, J., M. Crimmins, and G. Owen. 2011. Finding a place for climate science in the rural West. *Rural Connections* 5: 5-10.*

Faulstich, H. 2012. *Reconstructed cool- and warm-season precipitation over the tribal lands of northeastern Arizona.* Master's Thesis. School of Geography and Development, University of Arizona.*

Frisvold, G. and S. Deva. 2012. Farm Size, Irrigation Practices, and Conservation Program Participation in the U.S. Southwest. *Irrigation and Drainage* (In Press).

Frisvold, G. and K. Konyar. 2012. Less Water - How Will Agriculture in Southern Mountain States Adapt? *Water Resources Research* 011WR011057RR. (In Press)

Garfin, G., H. Hartmann, M. Crescioni-Benitez, T. Ely, J. Keck, J. Kendrick, K. Legg, and J. Wise. 2011. Climate-Friendly Park Employees: The Intermountain Region's climate change training assessment. *Park Science* 28(1): 30-36.*

Garfin, G., A. Jardine, R. Meredith, M. Black, A. Ray, J. Overpeck, A. Nacu-Schmidt, and A. Tangreen. 2012. Assessment of Climate Change in the Southwest United States: a Technical Report Prepared for the U.S. National Climate Assessment. *Technical Input to the National Climate Assessment.* Submitted on March 1, 2012.*

Garfin, G. and T. Kong. 2012. *Observed and Projected Climate Impacts for the City of Tucson.* A White Paper prepared for the City of Tucson Office of Conservation and Sustainable Development. 43 pp.*

Gaston, T. 2012. *Agricultural Water Demand along the Lower Colorado River Mainstem: Developing and Testing a Three-Model Approach for Econometric Analysis.* Master's Thesis. University of Arizona, Department of Agricultural & Resource Economics.

Guido, Z. 2011-12. *Southwest Climate Outlook* feature articles. http://www.climas.arizona.edu/outlooks/swco *

Guido, Z. 2011. *Hydrologic Extremes and Water Management in a Warmer World – California Perspectives*. Workshop Report. http://www.climas.arizona.edu/files/climas/workshops/05-19-11/extremesworkshopreport-19may2011-final.pdf *

Hartmann, H., J. Buizer, P. dos Santos, R. Moss, L. Patton, and L. Welling. 2011. Appendix 4 - Participatory scenario planning in regional and sectoral stakeholder activities in the National Climate Assessment. *In Scenarios and Regional Summaries, Report to National Climate Assessment Development and Advisory Committee.* Ad hoc Working Group 3. May 13, 2011. Washington, DC.*

Hurd, B., C. Goemans, G. Frisvold, and J. Stone. 2011. Estimated Impacts of Climate Change Legislation on New Mexico Agriculture. *Bulletin 801, Agricultural Experiment Station.* College of Agricultural, Consumer and Environmental Sciences. Las Cruces: New Mexico State Univ. http://aces.nmsu.edu/pubs/research/economics/BL801.pdf

Koracin, D., R. Vellore, D. Lowenthal, J. Watson, J. Koracin, T. McCord, D. DuBois, L. Antony Chen, N. Kumar, E. Knipping, N. Wheeler, K. Craig, and S. Reid. 2011. Regional source identification using Lagrangian stochastic particle dispersion and HYSPLIT backward-trajectory models. *Journal of the Air & Waste Management Association* 61(6): 660-672.

National Research Council. 2012. The National Weather Service Modernization and Associated Restructuring: A Retrospective Assessment. *Committee on the Assessment of the National Weather Service's Modernization Program.* National Academy Press: Washington, D.C. (Hartmann is a co-author)*

O'Lenic, E., H. Hartmann, M. Ou, K. Pelman, and S. Handel. 2011. An emerging protocol for research-to-operations (R2O) at CPC. In *Climate Prediction S&T Digest*, Science and Technology Infusion Climate Bulletin Supplement. National Weather Service, Silver Spring, MD.*

Quijada-Mascareñas, A. 2012. *Transborder Climate: Adaptation Without Boundaries/Clima Transfronterizo: Adaptación sin Fronteras.* February 2012 Newsletter Report. http://www.climas.arizona.edu/outlooks/tbc *

Routson, C., C. Woodhouse, and J. Overpeck. 2011. Second century megadrought in the Rio Grande headwaters, Colorado: How unusual was medieval drought? *Geophysical Research Letters* 38, L22703, doi:10.1029/2011GL050015.

Schuster, E., B. Colby, L. Jones, and M. O'Donnell. 2012. *Understanding the Value of Water in Agriculture: Tools for Negotiating Water Transfers*. Guidebook. http://www.climas.arizona.edu/files/climas/project-documents/public/value-water-agriculture-12-23-11.pdf. Also in Spanish: *Entendiendo el Valor del Agua en la Agricultura: Herramientas para Negociar Intercambios de Agua*. http://www.climas.arizona.edu/files/climas/project-documents/public/valor-de-agua-en-agriculture-2012.pdf *

Wall, T., G. Garfin, and J. Galayda. 2012. *Evaluating Our Capacity: A Discussion of Capability for Ongoing Climate Assessment in the Colorado River Basin.* Report http://www.climas.arizona.edu/files/climas/pubs/crb-workshop-report-2011.pdf *

Wilder, M., C. Scott, N. Pineda-Pablos, R. Varady, and G. Garfin. 2012. *Moving Forward from Vulnerability to Adaptation: Climate Change, Drought, and Water Demand in the Urbanizing Southwestern United States and Northern Mexico: Case studies in Ambos Nogales, Puerto Peñasco, Tucson, and Hermosillo.* Tucson, AZ: Udall Center Publications. http://udallcenter.arizona.edu/sarp/pdf/Casebook.pdf

* Denotes publications from which information has been communicated to decision makers and stakeholders. Please see project descriptions for further descriptions of the specific decision makers and stakeholders to whom the information has been communicated.