



2014 -2015  
ANNUAL PROGRESS REPORT



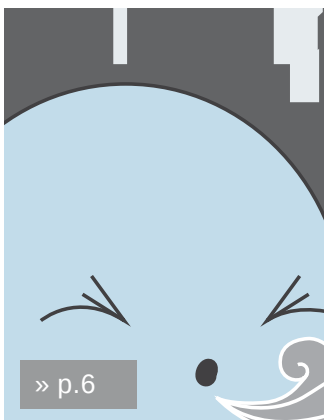
# ADAPTING TO CLIMATE VARIABILITY, THRESHOLDS, AND EXTREMES IN THE SOUTHWEST: THE CLIMATE ASSESSMENT FOR THE SOUTHWEST (CLIMAS)



DANIEL FERGUSON

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## 2014 - 2015 ANNUAL PROGRESS REPORT



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The work highlighted in this report is supported by the National Oceanic and Atmospheric Administration's Climate Program Office through grant NA12OAR4310124.

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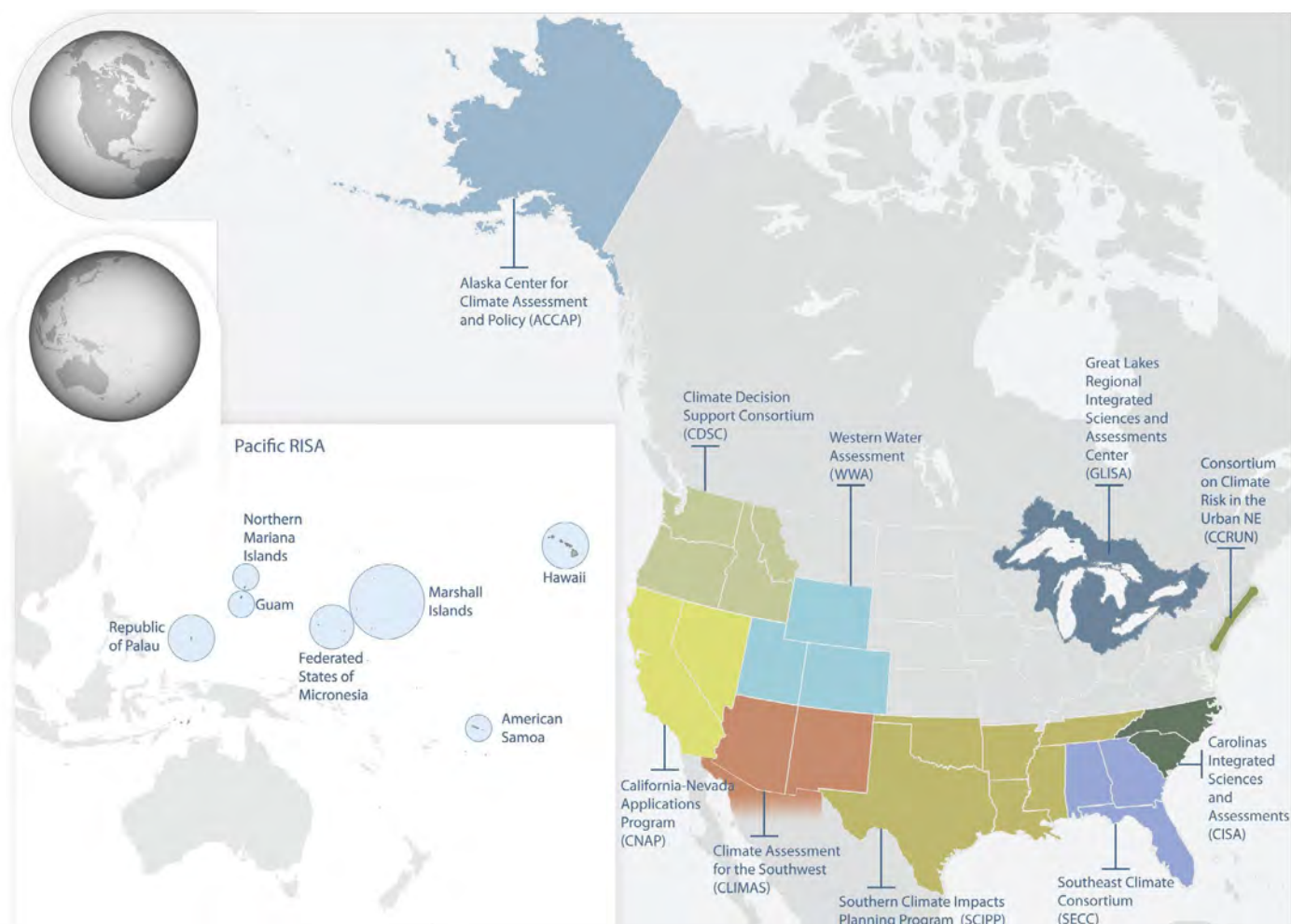
# RISA



## A Regional Approach to Climate Services: Regionally Integrated Sciences and Assessments (RISA)

In the mid-1990s, the National Oceanic and Atmospheric Administration (NOAA) created the RISA program to support research that addresses complex climate sensitive issues of concern to decision makers and planners at a regional level. The number of these programs, primarily based at universities,

has grown over the last 15 years as the need for climate information in support of decision making has also increased. As of July 2015, 11 RISA teams are funded, covering much of the United States and U.S. territories in the Pacific.





# Climate Assessment for the Southwest (CLIMAS)

## **CLIMAS, established in 1998, is the RISA program in the Southwest.**

The primary focus of the program is Arizona and New Mexico, although members of the CLIMAS team conduct research around the world. Headquartered at the University of Arizona's Institute of the Environment, CLIMAS also includes a core group of investigators at New Mexico State University as well as affiliated researchers throughout the West. The CLIMAS mission is to improve the region's ability to respond sufficiently and appropriately to climatic events and changes. The program promotes participatory, iterative research involving scientists, decision makers, resource managers, educators, and others who need more and better information about climate and its impacts. CLIMAS investigators conduct research about the nature, causes, and consequences of climate change and variability in the southwestern United States, providing valuable information to decision makers in a variety of fields, including water and fire management, agriculture, ranching, and public health. The program also supports efforts to improve climate forecasting in the region. Since its establishment more than 15 years ago, CLIMAS has built a large, diverse network of stakeholders and partners who have worked together on a tremendous range of projects. This report highlights the work in which CLIMAS was engaged between June 2014 and May 2015.

## **2014–15 CLIMAS Team**

### **PRINCIPLE INVESTIGATORS**

Heidi Brown, Bonnie Colby, Andrew Comrie, Michael Crimmins, David DuBois, Daniel Ferguson (Program Manager), George Frisvold, Gregg Garfin, Jonathan Overpeck (Lead PI), Margaret Wilder, Connie Woodhouse

### **STAFF RESEARCHERS**

Ben McMahan, Gigi Owen, Emily Huddleston, Anna Masayeva, Ryan Thomas

### **GRADUATE STUDENTS**

Rebecca Armenta, Antonio Arredondo, Ting Bai, Rebecca Brice, Mindy Butterworth, Gouro Camara, Andrew Clarke, Dari Duval, Emery Eaves, Mia Hammersley, Ron Klawitter, Brewster Malevich, Trevor McKellar, Noppanaree Puarattana-aroonkorn, Elizabeth Smith, Yizhi Zhao

### **RESEARCH AFFILIATES**

Tim Brown, Julie Brugger, Julia Cole, Zack Guido, Katharine Jacobs, Diana Liverman, Alison Meadow, Kiyomi Morino, Jeremy Weiss

### **CLIMATE AND SOCIETY FELLOWS**

2014 – Chris Guiterman, Ling-Yee Huang, Rebecca Lybrand, Sarah Truebe; 2015 – Christina Greene, Valerie Rountree, Eric Magrane, Bhuwan Thapa

# CLIMAS BY THE NUMBERS 2014-15

## Outputs

40

PRESENTATIONS  
GIVEN TO  
STAKEHOLDER  
AND ACADEMIC  
AUDIENCES

4

WORKSHOPS  
AND TRAININGS  
FACILITATED

8

PEER-REVIEWED  
ACADEMIC  
ARTICLES  
PUBLISHED

6

BOOK CHAPTERS  
PUBLISHED

3

MASTER'S  
THESES  
FINISHED

2

PHD  
DISSERTATIONS  
FINISHED

9

STAKEHOLDER  
REPORTS  
PRODUCED

15

CLIMATE  
NEWSLETTERS  
DISSEMINATED

24

UNIVERSITY  
STUDENTS  
FUNDED

11

NEW PROJECTS  
STARTED

13

YOUTUBE VIDEOS  
PRODUCED

16

PODCASTS  
PRODUCED

85

BLOG POSTS  
WRITTEN



## Arizona Business Resilience Initiative -An Initiative To Support Arizona's Business Community In Managing Climate Risk

**CLIMAS Investigators:** B. McMahan, G. Owen

The Arizona Business Resilience Initiative (ABRI) is focused on developing a methodology for assessing business opportunities and managing risks to their operations associated with climate change and climate variability. Working with business partners, this project aims to answer two questions: 1) Based on current state-of-knowledge in climate change impacts and vulnerability assessment, what are the most probable impacts on a company's operations and projections due to climate change? 2) With an understanding of the possible impacts, what are actions that can be taken to anticipate or mitigate these risks, or to position the company to take advantage of new opportunities that anticipate and adapt to climate change?

*Importance:* This project will build new avenues for engagement between the University of Arizona and the private sector. It applies University resources and expertise to develop a replicable framework with participating businesses that will significantly enhance their ability to react and respond to climate risks specifically, and the private sector's resilience to global changes more generally.

*Additional support provided by* The University of Arizona's Office for Research and Discovery

## Building a Regional Climate Database: Integrating Climate Data into Ecological Analysis, Monitoring, and Restoration

**CLIMAS Investigators:** B. McMahan, M. Crimmins

This project is being conducted in collaboration with regional ecological analysis, monitoring, and restoration groups to facilitate their use of climate data in their regular operations and in their long-term planning/analysis. The impact of climate variability and change, especially as temperature and precipitation regimes shift, necessitates a better understanding of these shifts, as well as the implications these changes have for practices of ecological management and restoration.

*Importance:* This project addresses ecological and environmental issues that are linked to climate of the Southwest and opens up collaborations with new stakeholders and collaborators regarding analysis and mitigation of these changes.

# NEW AREAS OF RESEARCH AND PARTNERSHIP

## RISA: An Organizational Ethnography

**CLIMAS Investigator:** A. Meadow

The RISA program was founded in 1995 as an experiment in the delivery of climate information to decision makers. This project applies organizational ethnographic methods to develop a comprehensive history of the program and a description of its structure and function. The 20-year anniversary of the RISA program is an excellent time to reflect upon how RISA was created, how it developed, and what other boundary and climate service organizations can learn about structuring their programs to optimize climate service delivery, collaborative knowledge development, and learning within the organizations.

*Importance:* Understanding how the broader RISA program was founded, how it has developed over the last 20 years, and how it currently functions can provide us with valuable insights into how to build and maintain other climate services or climate-focused boundary organizations.



DAVID DUBOIS

## Arizona's Views on Climate Change

**CLIMAS Investigators:** G. Garfin, J. Overpeck

Arizonans have long dealt with high temperatures and limited water resources, and climate change may increase the magnitudes of these challenges by causing increases in heat and the severity and frequency of droughts. This project summarizes the results of a survey of public opinion that was commissioned by the University of Arizona and Stanford University to provide a better understanding of how the Arizona public views this issue.

*Importance:* Understanding how the public views climate issues is of considerable interest to a wide range of people, including policymakers, resource managers, health officials, researchers, educators, and others. Although many national surveys have described climate change attitudes, these studies have interviewed only small samples of Arizona residents and have yet to explore their views in depth.

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*Additional support provided by* The University of Arizona's Institute of the Environment and Stanford University

## Exploring the Use of Climate and Remote Sensing Data to Support Drought Monitoring Across the Southwest U.S.

**CLIMAS Investigators:** M. Crimmins, J. Weiss

A new effort supported by a recent grant spurred the development of a tool called DroughtView, which combines cutting-edge online geovisualization tools with remote sensing products targeted at detecting drought conditions. DroughtView builds on the success of its precursor, RangeView, which was developed with the guidance of agriculturists and resource managers with a need for environmental monitoring data. The tools in DroughtView are being used to monitor biweekly changes in land surface greenness conditions as a proxy for drought impacts at very fine spatial scales across the Southwest U.S.

*Importance:* Drought monitoring across the Southwest U.S. is a challenging task given complex topography, seasonal climate, and sparse monitoring networks. Exploring the use of remote sensing imagery to support drought monitoring provides an important complementary monitoring tool for resource managers, farmers, ranchers, and decision makers.

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*Additional support provided by* NOAA Sectoral Applications Research Program and National Integrated Drought Information System





## Southeast Arizona Agricultural Weather and Climate Working Group

**CLIMAS Investigators:** M. Crimmins, J. Weiss

The University of Arizona Cooperative Extension and the National Weather Service (NWS) in Tucson developed a working group focused on engaging the agricultural community of southeast Arizona. The working group assesses information needs, provides training and technical support, conducts applied research, and develops new decision-support tools.

*Importance:* Orchards and vineyards in southeast Arizona represent an important and growing agricultural industry in the region and are especially sensitive to weather and climate extremes like freeze events, hail, wind, floods, and drought. The local NWS office expressed interest in forming a stronger partnership with the agricultural community in the region and approached the UA Cooperative Extension and CLIMAS to help facilitate this interaction.

*Additional support provided by* the U.S. Dept. of Agriculture Southwest Regional Climate Hub



## Western Adaptation Alliance – A Collaboration Project for Adaptation and Resilience to Climate Extremes

**CLIMAS Investigator:** G. Garfin

This project is designed to assist regional urban network managers of the Western Adaptation Alliance (WAA) in communicating with key constituencies in their communities to broaden support for action on climate adaptation and improve preparedness. Specifically, this involves keeping an inventory of major extreme events involving temperature extremes, flooding, drought, fire, and wind for each WAA city and across the region; recording specific actions taken following those events; developing narratives for each extreme impact; and creating a toolkit for the highest priority impact—extreme heat events.

*Importance:* Communicating about climate change can be tough in politically conservative states. Alternative messaging about climate variability and resilience can provide a means to communicate effectively to motivate voters and elected officials to endorse and act to increase preparedness for climate extremes.

*Additional support provided by* the city of Las Vegas and the Urban Sustainability Directors Network



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1

## Defining Ecosystem Water Needs and Assessing Impacts of Climate Change and Water Diversion on Ecosystems of the Upper Gila River in New Mexico

**CLIMAS Investigator:** G. Garfin

- Using a multi-model average, future annual temperature projections show increases in the upper Gila River Basin of 2–3°C (~3.6–5.4°F), with the largest increases in the summer and fall.
- Using a multi-model average, future precipitation projections show decreases, with the largest decreases during the spring and summer.
- Low flows are projected to drop even farther in the future, and very high flows are expected to become higher, even as overall streamflow is projected to decrease.

2

## Disentangling the Influence of Antecedent Temperature and Soil Moisture on Colorado River Water Resources

**CLIMAS Investigators:** C. Woodhouse, R. Brice

- Cool season precipitation is the most important driver of water year flow in the Upper Colorado River Basin, explaining two-thirds of the total variance overall, while March-July temperatures only explain 8 percent.
- However, when flow is greater or less than typically expected, given cool-season precipitation, temperatures may be playing a role in either exacerbating or ameliorating the effect of cool-season precipitation on water year streamflow.

3

## Sectoral Impacts of Drought and Climate Change

**CLIMAS Investigator:** G. Frisvold

- Restoration of the Colorado River Delta requires permanent increases in base flows and periodic larger volumes of water for pulse flows. Although pulse flows require more water, obtaining water for these may actually be easier than for base flows because water could be obtained through short-term leasing arrangements rather than permanent transfers.
- Agriculture supports about one in five jobs directly in Yuma County in Arizona, but because of linkages with the rest of the economy, agriculture supports one in four jobs. Changes in water rights or allocations to agriculture would have significant impacts to the local economy.

## 4

## Southeast Arizona Agricultural Weather and Climate Working Group

**CLIMAS Investigators:** M. Crimmins, J. Weiss

- The greatest temperature threshold concern to agricultural production in southeast Arizona is freezing because of the sensitivity of vineyard and orchard operations.
- The concern about freezing events increases through the spring as vegetation continues to grow and becomes more sensitive to a freezing event. A series of freeze events occurred during winter and spring 2015.

## 5

## Arizona's Views on Climate Change

**CLIMAS Investigators:** G. Garfin, J. Overpeck

- A large majority of Arizona residents believe that the world's temperature has been rising (74 percent), that it is at least partly caused by human activity (78 percent), and that it will continue to rise if nothing is done to stop it (75 percent). More than half believe global warming has caused more droughts and storms around the world, as well as more forest fires and heat waves in Arizona.
- More people believe that federal or state action to prepare for or reduce the effects of global warming would help the Arizona economy than the proportion who believes government action would hurt the state economy or have no effect.
- Generally, Arizonans' views on global warming are not substantially different from those of the U.S. as a whole. Some responses indicate that Arizonans are more concerned than the rest of the nation that the impacts of climate change will hurt them personally (43 percent Arizona compared to 34 percent U.S.).

## 6

## Adaptation Strategies for Water and Energy Sectors in the Southwest

**CLIMAS Investigators:** B. Colby, G. Frisvold, C. Woodhouse, G. Garfin, R. Klawitter, D. Duval, A. Clarke, T. Duffy

- Well-structured water banking programs can significantly reduce the regional economic damages from water supply shortfalls and should be a key feature of climate change adaptation.
- Innovative features in programs to reduce crop irrigation, including new water banking initiatives, should be considered in the new phase of the Colorado River Basin System Conservation Program.

## 7

## Fostering Conducive Conditions for Climate Assessments: Collaborative Scenario Planning and the Colorado River Basin Study

**CLIMAS Investigators:** G. Garfin, M. Hammersley

- People with greater participation and access to influence on the scenario planning process generally reported that the process met their needs and fostered the understanding of others, whereas people with less participatory power and access to influence generally reported that the scenario planning process was not as effective and did not meet their needs. substantially different from those of the U.S. as a whole. Some responses indicate that Arizonans are more concerned than the rest of the nation that the impacts of climate change will hurt them personally (43 percent Arizona compared to 34 percent U.S.).

## 8

## Climate Mitigation and Agriculture: Public Policy Education

**CLIMAS Investigators:** G. Frisvold, G. Camara, N. Puarattana-aroonkorn

- A cap-and-trade program with domestic agricultural offsets for carbon sequestration from tree planting may provide significant water conservation co-benefits. Because such a policy would act as a groundwater pumping tax, it would reduce agricultural water use significantly in the West.
- Reducing fertilizer use and retiring land in the Mississippi Basin could also contribute to reducing hypoxia problems in the Gulf of Mexico. While absolute pesticide and fertilizer use would decline nationally, some regions would experience significant increases in applications per acre. This means there could be potential hotspots of chemical and fertilizer use in some watersheds.



DAVID DUBOIS

## Southwest Climate Podcasts

**CLIMAS Investigators:** B. McMahan, M. Crimmins, G. Frisvold, B. Colby, D. Ferguson, G. Garfin, E. Huddleston, Z. Guido, R. Thomas

CLIMAS scientists discuss climate-related issues in monthly climate podcasts and special podcast series. The podcasts synthesize information from disparate sources and add regional context for the Southwest. The podcasts also bring in the latest climate science, covering climate-related topics with nuance but not shrouded in technical jargon. This year, CLIMAS has grown the audience of the Southwest Climate Podcast, expanded into two new podcast series, and explored new ways to distribute existing podcast series.

- **1075'**— Shortage on the Colorado River explores what the first ever shortage declaration on the Colorado River would mean to those living in the Southwest. The figure 1,075' refers to the elevation of Lake Mead—in feet above sea level—that serves as the trigger for shared shortage restrictions. While this has never happened before, after years of drought and ever-increasing demands on the river, the latest projections from the Bureau of Reclamation suggest the lake could drop below 1,075' as soon as early 2015. In this series, we attempt to demystify the rules and regulations that govern water use on the Colorado River and discuss what it means to the people and sectors across Arizona when a shortage occurs. It was distributed on the CLIMAS listserv, the CLIMAS blog, and on Twitter, FaceBook, and YouTube. <http://www.climas.arizona.edu/research/1075-shortage-colorado-river-climas-podcast-series>
- **Southwest Climate Update—Mini Podcast** is a pilot podcast series that focuses on quick and timely reporting on important climate news and information. It emphasizes stories that relate to the Southwest as well as climate-related news that illustrate the impact of climate on national or global scales. This podcast is also released as a video mini-podcast on the CLIMAS YouTube Channel in which images, maps, and video supplements illustrate the concepts discussed in the podcast. <http://www.climas.arizona.edu/podcast/southwest-climate-update-may-1-2015>
- **Speaking of Climate...** is a pilot podcast series that includes conversations with researchers and stakeholders about climate-related issues. This podcast expands our focus broader than just the Southwest and takes advantage of the numerous people who work on climate science, communication, outreach, education, and engagement on a daily basis. It is distributed on the CLIMAS listserv, CLIMAS blog, Twitter, FaceBook, and YouTube. <http://www.climas.arizona.edu/podcasts/speaking-climateconversations-about-climate-science-society>



## Southwestern Oscillations: News, Information, and Commentary

**CLIMAS Investigators:** B. McMahan, M. Crimmins, G. Garfin, D. Ferguson, G. Frisvold, E. Huddleston, Z. Guido, G. Owen

Southwestern Oscillations blog is a hub for news, information, and commentary about CLIMAS research and climate-related issues. The blog is regularly updated with news and information on CLIMAS research projects and publications; workshops, seminars, colloquia, and presentations; outreach activities (e.g., podcasts, presentations, Southwest Climate Outlook); feature articles and summaries on climate research and climate related issues; and blog-specific content such as “Notes from the Field” reports and “Ask an Applied Climatologist.” <http://www.climas.arizona.edu/blog>

## The Southwest Climate Outlook

**CLIMAS Investigators:** B. McMahan, G. Garfin, M. Crimmins, D. DuBois, E. Huddleston, Z. Guido

CLIMAS continues to produce the Southwest Climate Outlook (SWCO), a monthly publication that summarizes climate and weather information from disparate sources in nonscientific language for more than 1,600 people. Monthly issues are found here: <http://www.climas.arizona.edu/swco>

This year, a number of interactions occurred across social media regarding SWCO content. In particular, members of our regional network shared key points from SWCO articles on their own social media. This effort has also begun to expand to larger networks via shares and retweets outside of our own network of followers.

# KEY PUBLICATIONS

Ault, T., J. Cole, **J. Overpeck**, G. Pederson, and D. Meko. 2014. Assessing the risk of persistent drought using climate model simulations and paleoclimate data. *Journal of Climate* 27(20):7529-7549. <http://dx.doi.org/10.1175/JCLI-D-12-00282.1>

Projected changes in global rainfall patterns will likely alter water supplies and ecosystems in semiarid regions during the coming century. Instrumental and paleoclimate data indicate that natural hydroclimate fluctuations tend to be more energetic at low (multidecadal to multicentury) than at high (interannual) frequencies. State-of-the-art global climate models do not capture this characteristic of hydroclimate variability, suggesting the models underestimate the risk of future persistent droughts.



**Meadow, A., D. Ferguson, Z. Guido, A. Horangic, G. Owen, and T. Wall.** 2015. Moving toward the deliberate coproduction of climate science knowledge. *Weather, Climate, and Society* 7(2):179-191. <http://dx.doi.org/10.1175/WCAS-D-14-00050.1>

Coproduction of knowledge is believed to be an effective way to produce usable climate science knowledge through a process of collaboration between scientists and decision makers. This article presents five approaches to collaborative research to help structure the coproduction process. By using established collaborative research approaches, scientists can be more effective in learning from stakeholders and more confident when engaging with stakeholders because there are guidelines to follow. They also can assess both the process and outcomes of collaborative projects, which will help the whole community of stakeholder-engaged climate scientists learn about the coproduction of knowledge.

Bark, R., **G. Frisvold**, and K. Flessa. 2014. The role of economics in transboundary restoration water management in the Colorado River Delta. *Water Resources and Economics* 8:43-56. <http://www.sciencedirect.com/science/article/pii/S2212428414000516>

This article illustrates the potential of fundamental economic concepts (opportunity cost, marginal analysis, and Pareto-improving compensation) in developing options to provide ecological restoration flows to the Colorado River Delta. It addresses the needs of stakeholders desiring delta restoration with policy options and feasibility analysis to achieve that objective.

**Liverman, D., G. Garfin, S. Doster, K. Bao, F. Gladstone, J. Krosnick, B. MacInnis, and J. Overpeck.** 2015. *Arizona's Views on Climate Change - Executive Summary*. Institute of the Environment, Tucson, AZ. <http://www.environment.arizona.edu/sites/default/files/climate-survey/ExecutiveSummary.pdf>

This report summarizes the results of a public opinion survey that was commissioned by the University of Arizona and Stanford University to provide a better understanding of how the Arizona public views climate change. Results improve our understanding of stakeholder attitudes on key climate and environmental issues.

Colby, B., **G. Frisvold**, and M. Mealy. 2015. Managing Climate Risks Through Water Trading. In Burnett, K., et al (eds.). Routledge *Handbook of Water Economics and Institutions*. New York: Routledge.

This book chapter examines the potential for voluntary water trading and improved forecasting to mitigate water supply risks from climate risk in the Lower Colorado River Basin. For stakeholders, it illustrates how seasonal summer weather forecasts can facilitate short-term water transfers and mitigate supply risks.



**Frisvold, G.** 2015. The Economic Contribution of Agriculture in Yuma County. In Noble, W. (ed.). *A Case Study in Efficiency: Agriculture and Water Use in the Yuma, Arizona Area*. Yuma, AZ: Yuma County Agriculture Water Coalition.  
<https://wrrc.arizona.edu/case-study-in-efficiency>

This chapter applies input-output analysis to both direct and indirect contributions of agriculture to Yuma’s economy, including output, value added, and jobs. Stakeholders in Yuma (both agriculture and local government officials) are concerned that drought and Colorado River shortages will increase pressure to alter property rights to water in Yuma, negatively affecting agriculture and the county’s economy as a whole. This work was in direct response from stakeholder requests for analysis to respond to U.S. Bureau of Reclamation planning documents.

Díaz-Caravantes, R. and **M. Wilder**. 2014. Water, cities and peri-urban communities: Geographies of power in the context of drought in northwest Mexico. *Water Alternatives* 7(3):499-517.  
<http://www.water-alternatives.org/index.php/alldoc/articles/vol7/v7issue2/261-a7-3-4/file>

This article examines geographies of power of the urban-rural interface in Sonora, Mexico. It argues that urban water augmentation strategies reveal a distinct set of urban-peri-urban relations of unequal social power, in which peri-urban water resources are transferred to urban areas. This finding reflects the water demands of powerful, politically connected urban populations and large irrigation districts over the last three decades (1981–2010) in northwest Mexico. During this time period, peri-urban small-scale communal farmers, or ejidatarios, lost access to their water as it was moved or used to supply the needs of Hermosillo’s expansion.



## Climatic Sensitivities of Navajo Forestlands: Use-Inspired Research to Guide Tribal Forest Management

**CLIMAS Investigators:** C. Guiterman, D. Ferguson, C. Woodhouse, M. Crimmins

**Partner:** Navajo Forestry Dept.

Climate change is profoundly affecting forests throughout the Southwest. Tribal nations are at particular risk to these effects due to their reliance on ecosystem services provided by healthy forests. Tasked with managing more than five million acres of forests and woodlands, the Navajo Forestry Dept. has identified the need to assess sensitivities of their forests to drought and climate change. This project involved working with Navajo Forestry Dept. foresters to quantify the climatic drivers of forest growth in the Chuska Mountains. The study provided an improved assessment of forest response to climate change that is vital to natural resource planning and management.

### SELECTED RESULTS:

- Winter precipitation was the most important variable in controlling tree growth among plots in the Chuska Mountains. Summer temperatures and vapor pressure deficit were secondary.
- Among plots, landscape setting (slope steepness and aspect in particular) was the primary driver of variability. Trees growing on steep slopes with shallow soils and more southerly exposure were more affected by drought and increased temperatures. For managers, this means that those sites could be more likely to experience higher tree mortality in the future, while trees growing on more sheltered sites might be relatively more resilient to future climate extremes.
- Substantial diversity exists in the age structures of forest plots. This means that recruitment is ongoing and the range of tree ages present on the forest could help promote forest resilience in the future by maintaining tree dominance through drought episodes.

### FINAL REPORT:

*Climatic Sensitivities of Navajo Forestlands: Use-inspired Research to Guide Tribal Forest Management.*

<http://www.climas.arizona.edu/sites/default/files/pdfclimas-fellow-finalreport2014guiterman.pdf>



## Achieving Scientific Literacy in the Classroom: A Climate Science and Law Curriculum

**CLIMAS Investigator:** L. Huang

The purpose of this project was to develop a curriculum for law students that integrated science and the law. Both law and science professors were queried regarding the most important scientific topics to teach that were related to law. Based on these discussions and review of readily available curricula and literature on scientific literacy skills, the curriculum topics for this project were identified, revised, and edited to fit the constraints of the University of Arizona James E. Rogers College of Law spring 2015 post-February bar schedule. Readings and other class material were identified to accompany the in-class lectures and discussion.

Huang taught this curriculum for LAW 6980: Integrating Science and the Law in Practice at the UA's College of Law in spring 2015. The curriculum focused on teaching basic scientific literacy skills, namely understanding the process of scientific inquiry and gaining basic data interpretation skills. The course helped orient students within the complex scientific landscape in which law and policymaking occurs.

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### FINAL REPORT:

*Achieving Scientific Literacy in the Classroom: A Climate Science and Law Curriculum.*

[http://www.climas.arizona.edu/sites/default/files/CLIMAS-Fellow-FinalReport2014\\_Huang.pdf](http://www.climas.arizona.edu/sites/default/files/CLIMAS-Fellow-FinalReport2014_Huang.pdf)

## Cultivating a Climate of Cave Conservation Awareness: A Synthesis of Current Speleothem Sampling Methods and Best Practice Recommendations

**CLIMAS Investigator:** S. Truebe

Speleothems, or cave formations such as stalagmites, are useful archives of past climate change. They form over hundreds of thousands of years and can be dated using uranium incorporated into the speleothem structure. Rainfall has a particular oxygen isotope composition that is conserved as that rainfall drips through the soil and rock above the cave, enters the cave, and deposits calcium carbonate in the form of a speleothem. Sampling the isotope chemistry must be done along the growth axis, which generally requires speleothems to be removed from the cave. Speleothems are slow-growing, and are non-renewable resources on human timescales. Development of sustainable sampling methods to balance conservation and science ought to be a priority of the paleoclimate community. Thus, the objectives of this study were to develop a list of currently used speleothem sampling methods; increase transparency of speleothem selection and sampling methodology for scientists and other stakeholders; provide a forum for other cave stakeholders such as managers, owners, and recreational cavers to give feedback on currently used methods; and develop a set of best practice recommendations for sampling.

The Speleothem Sampling Recommendation Framework includes the best practices mentioned by survey respondents. This framework may prove to be a useful reference tool for scientists new to working with stakeholders and for cave managers and other cave stakeholders to recognize that they can have a voice in the sampling process.

### SELECTED RESULTS:

- Primarily, scientists use permanent removal of speleothems from the cave (100 percent). Other techniques include removal with pre-screening for age dates or dripwater chemistry (20 percent), coring of stalagmites (20 percent), removal of broken stalagmites (18 percent), and removal and replacement or replica (18 percent). More than one-third of responding scientists were distressed by the current methods they used, commenting for instance, "I am not happy with the brutal methods I usually use, but I have few options" given constraints on time and funding.
- The top five methods favored by the caving community were coring (79 percent); removal of broken stalagmites (74 percent); removal with (pre)screening (67 percent), removal and archiving (64 percent); removal and replacement/ replica (48 percent), only shortly ahead of the sixth method, permanent removal (47 percent).

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### FINAL REPORT:

*Cultivating a Climate of Cave Conservation Awareness: A Synthesis of Current Speleothem Sampling Methods and Best Practice Recommendations.* [http://www.climas.arizona.edu/sites/default/files/CLIMAS-Fellow-FinalReport2014\\_Truebe.pdf](http://www.climas.arizona.edu/sites/default/files/CLIMAS-Fellow-FinalReport2014_Truebe.pdf)



REBECCA LYBRAND

## Soil Not Dirt: The Surprising Connection between Soils and Climate in the Southwest U.S.

**CLIMAS Investigators:** R. Lybrand

**Research Collaborators:** S. Reed (Univ. of Arizona – Flandrau Science Center); J. Hmielowski (Washington State Univ.).

The primary objective of this project was to create a short film to document the field science research process of studying how climate impacts soils across the Santa Catalina Mountains north of Tucson, Arizona. The film was designed to engage viewers by using an energetic, first-person perspective on the exploration of soils from desert scrub to mixed conifer forest. The Santa Catalina environmental gradient is comparable to a latitudinal transect from southern Arizona to southern Canada, offering a stimulating perspective on fieldwork across diverse ecosystems.

The second part of the project involved writing two scripts to record with the film. The first script contained a “science message,” which presented the link between soil science and climate change using a formal, objective tone while maintaining audience interest with a first-person documentary film style. The second script employed a narrative story with a less formal “science story” tone, a technique found to increase audience comprehension and engagement.

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### FINAL VIDEO:

*Soil, Not Dirt: A Digital Journey Connecting Soils, Plants, and Climate.* <https://youtu.be/3JarDy53PLQ>

## The current 2015 Climate and Society Graduate Fellows began in January 2014. They are currently working on the following projects:

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**Christina Greene:** A history of prolonged droughts has long challenged the food system in the Southwest, and these challenges will become steeper under a future of climate change. This project seeks to better understand the vulnerability of the food system to drought by focusing on the impacts of the California drought on farmworkers. By identifying the needs of farmworkers during drought and evaluating the distribution of drought relief boxes through community food banks, this research seeks to connect the environmental and social dimensions of drought, labor, and food insecurity.



**Eric Magrane:** This project involves designing and teaching a community course for the UA's Poetry Center called "Climate Change and Poetry." Climate change is both a scientific and a social issue. It is a threat to life on Earth, as well as an opportunity for social change and environmental justice. A growing body of poetry addresses climate change and this course will use poems as boundary objects to both communicate climate change and to examine its different frames or narratives. It will explore what role the imaginative and emotional resonances of poetry might have in the way we think about adaptation and mitigation.



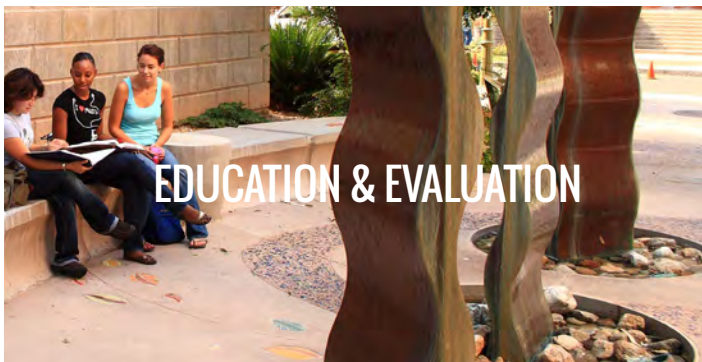
**Valerie Rountree:** In March 2015, the Tucson mayor's office held a half-day summit on energy and the economy with policymakers and business owners in the city to discuss the economic opportunities associated with increasing energy and the use of renewable energy. This project will include three parts. First, a pre-summit survey of prospective attendees will be administered to get baseline data regarding participants' opinions and knowledge of energy efficiency. The results of the survey also will be used to tailor the content of the summit to participants' interests. Second, a post-summit survey of attendees will be administered to evaluate the impacts of the summit on attendee opinions, knowledge, and perceptions. And third, follow-up interviews will complement surveys to evaluate whether participants plan to implement energy efficiency measures.



**Bhuwan Thapa:** Nepal's water resources and agriculture sectors have been hit hard by climate variability and change. About 25,000 irrigation systems are managed by farmers and irrigate about 25 percent of the total irrigated area in Nepal. Though farmer-managed irrigation systems (FMIS) are considered robust, they are facing increasing climatic and non-climatic stresses, including competing water demands, frequent infrastructural damage from flooding and landslides, degraded water quality, and poor governance. This study will research FMIS adaptation strategies to strengthen their management capacity.

# CLIMAS PROJECTS: 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) themes. For the purpose of this report, CLIMAS projects are organized into the following eight areas of focus:



# Areas of Focus: Adaptation & Vulnerability

## Adaptation Strategies for Water and Energy Sectors in the Southwest

**CLIMAS Investigators:** B. Colby, G. Frisvold, C. Woodhouse, G. Garfin, R. Klawitter, D. Duval, A. Clarke, T. Duffy

**Research Collaborators:** Sonoran Institute; U.S. Bureau of Reclamation; U.S. Dept. of Agriculture; New Mexico Office of the State Engineer; The Nature Conservancy

**Partners:** Arizona Dept. of Water Resources; Central Arizona Project; Salt River Project; New Mexico Interstate Stream Commission; New Mexico State University; Lower Rio Grande Water Users Association; Western Resource Advocated; Environmental Defense; ProNatura; Western Governors Association; Western States Water Council; National Audubon Society

This project examines potential climate change and variability adaptation strategies related to water and energy in the Colorado River and Rio Grande basins, including northwestern Mexico. Researchers are investigating how climate influences the market price of water and are developing a menu of water and energy supply reliability tools and guidelines for using them.

Persistent drought and climate change affect water and energy costs, and hence choices made by farms, cities, and industrial water and energy users, as well as energy and water providers' operations. Increased temperatures will increase summer power demand in the Southwest due to higher energy requirements for indoor cooling, agricultural irrigation, and urban outdoor water use. Multi-decade drought will reduce hydropower generation. Water and power costs are likely to increase, leading to increased financial stress for households and businesses and resource management challenges in the water and energy sectors. This research investigates new methods for anticipating and adapting to climate impacts in the water and electricity urban supply sectors and for providing water for critical habitat needs.

### DELIVERABLES

1) Publications – Clarke, A. 2015. *Come Hell Or High Water Prices: A Household-Level Analysis Of Residential Water Demand*. Master's thesis. Dept. of Agricultural and Resource Economics, The University of Arizona.

Colby, B., G. Frisvold, and M. Mealy. 2015. Managing Climate Risks through Water Trading. In Burnett, K., et al (eds.). *Routledge Handbook of Water Economics and Institutions*. New York: Routledge.

Colby, B. 2014. Innovative Water Transactions to Meet Urban and Environmental Demands in the Face of Climate Change. In Easter, W. and Q. Huang (eds.). *Water Markets for the 21st Century: What Have We Learned?* New York, NY: Springer.

Duval, D. 2015. The Influence of Colorado River Flows on the Upper Gulf of California Fisheries Economy. Master's thesis. Dept. of Agricultural and Resource Economics, University of Arizona.

MacDonnell, L., R. Benson, B. Colby, R. Glennon, B. Udall, and C. Wilkinson. 2015. Navigating a Pathway toward Colorado's Water Future: A Review and Recommendations on Colorado's Draft Water Plan. Boulder, CO: Getches-Wilkinson Center for Natural Resources, Energy, and the Environment, University of Colorado Law School. This report provides conclusions and recommendations for the Colorado Water Plan, which will help shape and direct Colorado's water future. This addresses a stakeholder need for guidance on future water policy and planning.

2) Presentations by B. Colby – "Drought-proofing" Regional Water Supplies: How Effective Can We Be? Hydrologic Sciences Research Symposium. University of Colorado, April 2014. Provided information on economic tools and potential responses to climate effects on water

supply and demand to audience of water resource professional and stakeholders.

*Colorado River Basin: Innovations in Water Banking*. U.S. Dept. of Agriculture-National Institute for Food and Agriculture Conference. Tufts University, June 2014. Provided information on economic tools and potential responses to climate effects on water supply and demand to audience of water resource professional and stakeholders.

*Building Climate Change Resilience Into Water Sharing Agreements*. Universities Council on Water Resources Annual Conference. Boston, MA, June 2014. Provided information on economic tools and potential responses to climate effects on water supply and demand to audience of water resource professional and stakeholders.

*Water Banks: Protecting Colorado's Economy from Drought Impacts*. Invited Testimony for Colorado Legislative Hearing. Denver, CO, August 2014. Provided information on economic tools and potential responses to climate effects on water supply and demand to audience of elected officials, water resource professional, and stakeholders.

*Designing Economic Incentives to Improve Water Supply Reliability*. University of New Mexico Water Policy Conference. Albuquerque, NM, October 2014. Provided information on economic tools and potential responses to climate effects on water supply and demand to audience of water resource professional and stakeholders.

*Using Economic Incentives to Address Water Challenges*. Colorado River Research Group Workshop. Tucson, AZ, January 2015. Provided information on economic tools and potential responses to climate effects on water supply and demand to audience of water resource professional and stakeholders.

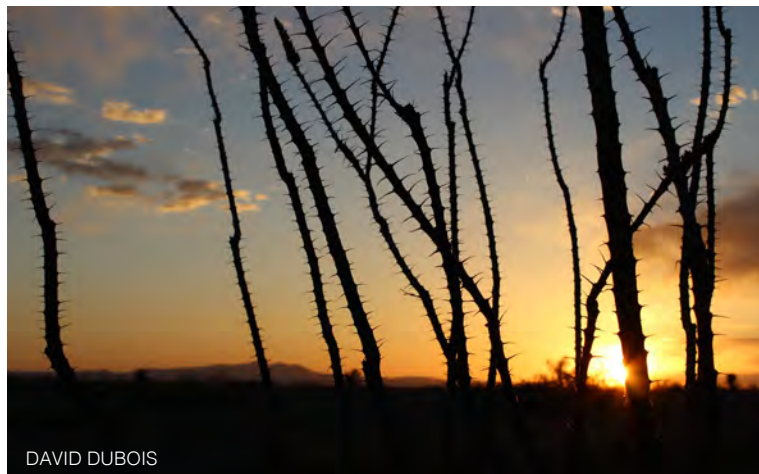
**Other Funding Sources:** NOAA Regional Climate Centers; NOAA Sectoral Applications Research Program; Univ. of Arizona Office of Arid Lands Studies; U.S. Bureau of Reclamation; Walton Family Foundation; Sonoran Institute; U.S. Dept. of Agriculture – Agriculture and Food Research Initiative. Enhancing Climate Resiliency for Agricultural Production on American Indian Lands of the Great Basin Region. Leveraged project housed at Univ. of Nevada, Reno. AFRI Grant, U.S. Dept. of Agriculture.

# CLIMAS Heat Extremes Assessment (HEAT) – Exploring the Cascading Effects of Climate Extremes in the Southwest

**CLIMAS Investigators:** B. McMahan, M. Wilder, G. Garfin, H. Brown, D. Ferguson, M. Crimmins, E. Eaves, G. Owen

**Research Collaborators:** City of Tucson; Pima Association of Government; Pima County Health Dept.; Arizona State Univ

Climate extremes pose serious threats to human health and place increasing demands on municipal services and infrastructure, and they threaten the long-term sustainability of a region. These extremes have implications for rapid response and emergency management, but they also amplify the effects of underlying social, economic, and environmental vulnerabilities and have numerous potential long-term consequences in terms of planning for and dealing with potential disasters. In the Southwest, heat presents a unique opportunity to study the intersection between an acute event (e.g., a multi-day heat wave), and underlying vulnerabilities and risks. It also presents an opportunity to look for cross-sector impacts and potential cascades of impacts.



DAVID DUBOIS

## DELIVERABLES

1) Presentation – McMahan, B. 2015. Health, Vulnerability, and the Cascading Effects of Climate Extremes: Collaborative Research in the Southwest. RISA Annual Meeting. Charleston, SC, January 2015. This presentation provided the opportunity to discuss possible approaches to researching social vulnerabilities, as well as the economic and environmental effects that amplify the impacts of climate on health.



## Arizona's Views on Climate Change

**CLIMAS Investigators:** G. Garfin, J. Overpeck

**Research Collaborators:** D. Liverman (Univ. of Arizona – Institute of the Environment); J. Krosnick, B. MacInnis (Stanford Univ.); K. Bao, F. Gladstone (Univ. of Arizona – School of Geography and Development)

Arizonans have long dealt with high temperatures and limited water resources, and climate change may increase the magnitudes of these challenges by causing increases in heat and the severity and frequency of droughts. Understanding how the public views climate issues is of considerable interest to a wide range of people, including policymakers, resource managers, health officials, researchers, educators, and others. Although many national surveys have described climate change attitudes, these studies have interviewed only small samples of Arizona residents and have yet to explore in depth the views of state residents. This report summarizes the results of a survey of public opinion that was commissioned by the University of Arizona and Stanford University to provide a better understanding of how the Arizona public views climate change. The results help guide the CLIMAS mission to serve the Southwest and its residents through research and outreach.

## DELIVERABLES

- 1) Publication – Liverman, D., G. Garfin, S. Doster, K. Bao, F. Gladstone, J. Krosnick, B. MacInnis, and J. Overpeck. 2015. Arizona's Views on Climate Change - Executive Summary. Institute of the Environment, Tucson, AZ. <http://www.environment.arizona.edu/sites/default/files/climate-survey/ExecutiveSummary.pdf>
- 2) Website – Arizona's Views on Climate Change website provides an overview of the project, methods, and results: <http://www.environment.arizona.edu/climate-survey>

**Other Funding Sources:** Univ. of Arizona – Institute of the Environment

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

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

**Research Collaborators:** C. Neri (Univ. Nacional Autonoma de México); R. Merideth (Univ. of Arizona – Udall Center for Public Policy); C. Presnall (TANGO International)

**Partners:** World Wildlife Fund; ProNatura; Sonoran Institute; Tucson Water; Agua de Hermosillo; U.S. Geological Survey; Comisión Nacional del Agua; Instituto Nacional de Investigaciones Forestales Agrícolas y Pecuarias

Adaptation in water management is a greatly revered yet poorly understood goal and concept. The U.S. suffers from an “adaptation deficit” (Jacobs et al. 2010), but there is little comprehensive research on how to advance adaptation. Case studies of how adaptation is actually being delivered and barriers to effective delivery (e.g., information, capacity, institutions) make up a critical missing component of existing adaptation research. This project addresses this gap both theoretically and methodologically in four study sites in the Arizona-Sonora region of the U.S.-Mexico border: Tucson, AZ; Yuma, AZ, and the Colorado River Delta; the Upper Gulf of California; and Hermosillo, Sonora. The key research questions guiding this project include a) what is the role of networks in governance and the implications for using climate knowledge; b) what are the most effective climate services to support efforts to adapt; and c) how can decision-support tools build institutional adaptive capacity. Researchers examine these questions via interactive semi-structured interviews, a webinar series on the border climate, and a scientist-stakeholder symposium. Project outputs include the pilot development of an institutional adaptive capacity index; presentation of results at professional meetings; papers in peer-reviewed journals, workshop and symposia reports; a webinar series; quarterly production of the Transborder Climate newsletter; and a project website.

## Western Adaptation Alliance: A Collaboration Project for Adaptation and Resilience to Climate Extremes

**CLIMAS Investigator:** G. Garfin

**Research Collaborators:** S. Leroy (Univ. of Arizona – Institute of the Environment)

**Partners:** Western Adaptation Cities (Salt Lake City, Park City, UT; Las Vegas, NV; Ft. Collins, Boulder, Lakewood, Denver, CO; Santa Fe, Las Cruces, NM; Flagstaff, Tucson, Phoenix, AZ; El Paso, TX)

The project is designed to help regional urban network managers of the Western Adaptation Alliance (WAA) communicate with key constituencies in their communities to broaden support for action on climate adaptation and to improve preparedness. Specifically, this involves taking inventory of major extreme events of five key climate impacts—temperature extremes, stormwater/floods, drought, fire, and wind—for each WAA city and across the region, recording specific actions taken following those events, developing narratives for each class of impact, and creating a toolkit for the highest priority impact—extreme heat events.



### DELIVERABLES

1) Presentation – Wilder, M. 2015. Desalination and Water Security at the U.S. Mexico Border. Annual Meeting of the Association of American Geographers. Chicago, IL, April 2015. Around the globe, desalination initiatives are underway with little attention to institutional, social, and other non-technical aspects of these infrastructure projects. Water managers, NGOs, and other stakeholders in the Arizona-Sonora border region need to be aware of the potential benefits and challenges of supplying major Southwestern cities with desalted water produced in Mexico in order to plan more effectively.

**Other Funding Sources:** NOAA – Regional Climate Services Directors; NOAA – Sectoral Applications Research Program (SARP)

### DELIVERABLES

1) Database – Includes data on climate extremes, impacts, preparedness, and response measures for five hazards: wind, heat, drought, flood, and fire. Stakeholders indicated they do not have this information in a coordinated, centralized manner.

2) Presentations – Garfin, G. and S. Leroy. 2015. Climate Extremes and Resilience for Intermountain West Cities. National Adaptation Forum. St. Louis, MO, May 2015. <http://www.nationaladaptationforum.org/>

Garfin, G., S. Leroy, and R. Tucci. 2014. Increasing Adaptation Resilience to Climate Extremes. CALS Poster Forum. Tucson, AZ, November 2014.

**Other Funding Sources:** City of Las Vegas; Urban Sustainability Directors Network

# Fostering Conducive Conditions for Climate Assessments: Collaborative Scenario Planning and the Colorado River Basin Study

**CLIMAS Investigators:** G. Garfin, M. Hammersley

The Colorado River Basin Supply and Demand Study, conducted by the U.S. Bureau of Reclamation, was an unprecedented attempt to bring together a variety of experts and stakeholders from the watershed to address the current imbalance between supply and demand from 2012 through 2060. The study is also the largest scenario-planning project ever to be conducted by the Bureau of Reclamation. While most scenarios are either an expert scenario model or a stakeholder-defined scenario, the study incorporated aspects from both models, creating a collaborative model. Researchers hypothesize that this collaborative scenario planning process makes it easier for stakeholders to find common ground on pathways to address common challenges, and that it fosters the use of climate change information in decision making. This project aims to evaluate the aforementioned hypotheses through critical evaluation of the basin study scenario planning activity and basin study participant responses to interview questions.



## DELIVERABLES

- 1) Publication – Hammersley, M. 2014. Fostering Conducive Conditions for Climate Assessments: Collaborative Scenario Planning and the Colorado River Basin Study. Water, Society, and Policy master's thesis. School of Natural Resources and the Environment, The University of Arizona, Tucson, AZ. Scenario planning partly improved multi-party cooperation and acceptance of climate change as a legitimate resource planning issue.
- 2) Presentation – Hammersley, M. 2014. Fostering Conducive Conditions for Climate Assessments: Collaborative Scenario Planning and the Colorado River Basin Study. Master's thesis presentation. The University of Arizona – School of Natural Resources and the Environment. Tucson, AZ, December 2014.

**Other Funding Sources:** NOAA Climate Program Office

## Metrics and Measurement of Adaptation

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

**Research Collaborators:** R. Varady, C. Scott (Univ. of Arizona – Udall Center for Public Policy)

In many arid regions of Latin America and North America, research teams are conducting studies on how water governance actors and networks are confronting the challenges of global change, including climate change and globalizing markets. Water governance actors—water managers, farmers and irrigators, non-governmental organizations, urban communities, and rural inhabitants—in these arid regions on the whole are knowledgeable and skilled in managing water supply and innovating new ways of meeting water demand, and they tend to be sophisticated users of climate information. However, less is known about the adaptation strategies that seek to achieve water security and environmental sustainability that are effective in these arid regions, and there is even less systematic knowledge about the adaptive capacity of water governance networks. In short, this project probes how adaptation and water security can be measured.

## DELIVERABLES

- 1) Workshop – Metrics and Measurement of Adaptation: Advances in Water Research in the Arid Americas. This meeting brought together a group of 27 researchers and water resources policymakers working to understand adaptation in water-short regions of the Americas and other arid-semiarid areas of the world, including Chile, Mexico, Argentina, Brazil, and the southwestern U.S. The goals of the meeting were to share research experiences from distinct contexts; begin to synthesize common or related findings from across the region; develop a special issue on the metrics of adaptation for submission to a high-impact journal (e.g., *Current Opinion in Environmental Sustainability*, *COSUST*); and discuss potential future collaboration on metrics and measuring adaptation.

**Other Funding Sources:** Univ. of Arizona – Udall Center for Public Policy



# Areas of Focus: Climate Science



## Defining Ecosystem Water Needs and Assessing Impacts of Climate Change and Water Diversion on Ecosystems of the Upper Gila River in New Mexico

**CLIMAS Investigator:** G. Garfin

**Research Collaborators:** H. Chang (Univ. of Arizona – Dept. of Atmospheric Sciences); M. Switanek (Univ. of Arizona – Dept. of Hydrology and Water Resources)

**Partners:** New Mexico Interstate Stream Commission; U.S. Bureau of Reclamation; The Nature Conservancy, New Mexico; Upper Gila Watershed Alliance

The goal of this project is to define the ecosystem water needs of the upper Gila River in New Mexico and to evaluate the probable ecological impacts of a diversion proposed under the Arizona Water Settlements Act, New Mexico Unit, considering existing conditions and changing climate. The CLIMAS portion of this project will develop and evaluate climate and hydrological change projections needed by project ecologists, biologists, and hydrologists to evaluate potential impacts of change on hydrological and ecological processes. The research was completed in July 2014, with publication of a report (described below). However, because the research and report are part of ongoing New Mexico policy discussions, there is need for follow-up with responses to critique and efforts to publish in a peer-reviewed journal.

### DELIVERABLES

1) Publication – Garfin, G., H. Chang, and M. Switanek. 2014. Chapter 3. Climate and Hydrology of the Upper Gila River Basin. In DGori, D., M. Cooper, E. Soles, M. Stone, R. Morrison, T. Turner, D. Propst, G. Garfin, M. Switanek, H. Chang, S. Bassett, J. Haney, D. Lyons, M. Horner, C. Dahm, J. Frey, K. Kindscher, H. Walker, and M. Bogan (eds.). Gila River Flow Needs Assessment. A Report by The Nature Conservancy. The Nature Conservancy in New Mexico, Santa Fe. This chapter examines historic and projected records of climate factors for the Southwest, with a focus on the upper Gila River Basin in New Mexico. This work addresses the climate change information needs of stakeholders in the Gila River Basin in New Mexico. <http://nmconservation.org/Gila/GilaFlowNeedsAssessment.pdf>

2) Media Coverage – Villagran, L. 2014. Gila Diversion's Price Tag One of Many unknowns. Albuquerque Journal. August 24, 2014.

Fleck, J. 2014. Stream Commission Votes to Divert Water from Gila River. Albuquerque Journal. November 24, 2014.

### Other Funding Sources:

The Nature Conservancy – U.S. Bureau of Reclamation WaterSmart Grant

# Disentangling the Influence of Antecedent Temperature and Soil Moisture on Colorado River Water Resources

**CLIMAS Investigators:** C. Woodhouse, R. Brice

**Research Collaborators:** G. Pederson (U.S. Geological Survey – Bozeman); A. Csank (Desert Research Institute); S. Gray (Alaska Climate Science Center; U.S. Geological Survey); S. McAfee (Univ. of Nevada – Dept. of Geography); G. McCabe (U.S. Geological Survey – Denver)

**Partners:** State of Colorado; Salt River Project; Denver Water; U.S. Bureau of Reclamation, Lower Colorado District; NOAA – Colorado Basin River Forecast Center

The main goal of this project is to better understand how a set of hydroclimatic factors (prior summer/fall soil moisture, cool season precipitation/snowpack, and late winter/spring temperatures) contribute to low annual flows on the Colorado River. Researchers are using a combination of instrumental data, tree-ring reconstructions, and downscaled CMIP5 projections to investigate the differing roles of these factors in both instrumental period droughts and droughts that have occurred over past centuries, including conditions in major sub-basins. Researchers are also testing the sensitivity of annual low flows to different CMIP5 scenarios of changes in soil moisture, winter precipitation, and winter/spring temperatures, and comparing climate conditions associated with historic/paleo low flows to those associated with low flows derived from downscaled projections.

## DELIVERABLES

1) Website – The Drivers of Drought in the Upper Colorado River Basin website describes the project and outcomes to date, and provides data and tools with project partners and stakeholders. U.S. Geological Survey and the Northern Rocky Mountain Science Center helped produce the website. <http://www.nrmssc.usgs.gov/ColoradoRiverWater>

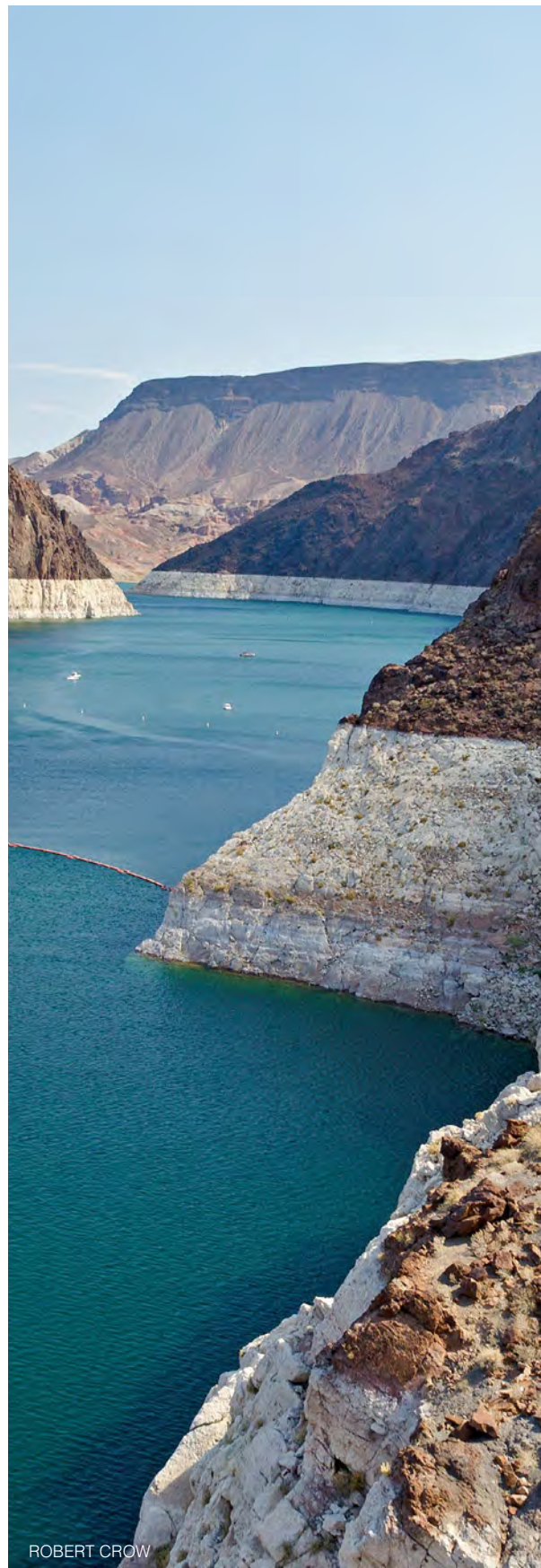
2) Presentations – Woodhouse, C., G. Pederson, K. Morino, and G. McCabe. 2015. Investigating the Role of Temperature in Mediating Relationships between Cool Season Precipitation and Water Year Streamflow in the Upper Colorado River Basin. Pacific Climate (PACLIM) Meeting. Pacific Grove, CA, March 2015.

Woodhouse, C., S. McAfee, G. McCabe, P. Miller, and G. Pederson. 2014. Evaluating the Influence of Precipitation, Temperature, and Soil Moisture on Upper Colorado River Basin Streamflow and Drought. American Geophysical Union. San Francisco, CA, December 2014.

Woodhouse, C. 2014. Collaborative Research on Upper Colorado River Basin Streamflow and Drought. Association of Pacific Coast Geographers Annual Meeting. Tucson, AZ, September 2014.

Woodhouse, C. 2014. Collaborative Research on Upper Colorado River Basin Streamflow and Drought. Bureau of Reclamation, Colorado River Hydrology Work Group Meeting. December 2014. This presentation was part of an ongoing collaborative effort with the Bureau of Reclamation to better understand hydroclimatic variability to manage water resources and anticipate the impacts of climate change.

**Other Funding Sources:** U.S. Dept. of the Interior – Southwest Climate Science Center



ROBERT CROW

# Areas of Focus: Communicating Science

## Climate in Context (RISA Book)

**CLIMAS Investigators:** G. Garfin, D. Ferguson, M. Crimmins, G. Owen, J. Brugger

**Research Collaborators:** K. Dow (Univ. of South Carolina); R. Meyer (California Ocean Science Trust); A. Parris, S. Close (NOAA Climate Program Office)

*Climate in Context* is an edited volume describing the development and implementation of the NOAA RISA program, an innovative program to research and develop experimental region-based climate services. The book covers scholarly contributions on use-inspired research in five key areas, including understanding the context of working with stakeholders and decision makers, understanding risk-based climate applications, supporting the development of knowledge networks, innovating regional climate services, and advancing science policy. The book editors are Adam Parris, Gregg Garfin, Kirstin Dow, Ryan Meyer, and Sarah Close. The book will be published by Wiley & Sons and the expected date of publication is January 2016.



### DELIVERABLES

1) Publication – Final manuscript of book sent to publishers in May 2015. Book scheduled to be published in January 2016.

**Other Funding Sources:** NOAA Climate Program Office

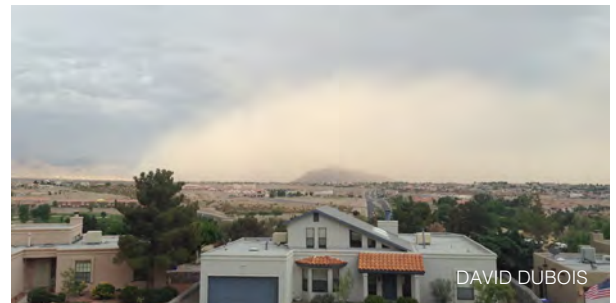
## Building Climate Science into Land and Water Conservation Planning and Decision Making in the American Southwest

**CLIMAS Investigators:** G. Garfin, J. Brugger, A. Meadow

**Research Collaborators:** B. Travis, E. Gordon, J. Barsugli, I. Rangwala (Western Water Assessment)

**Partners:** The Nature Conservancy; Mountain Studies Institute; NOAA Climate Program Office

This project connects two RISA programs, the Western Water Assessment (WWA) and CLIMAS with regional conservation planners and decision makers to improve climate adaptation planning and implementation by land managers in the American Southwest. A key challenge is to bring climate knowledge to bear on habitat and species conservation efforts underway in the region, and to move conservation projects beyond vulnerability assessments to adaptation planning and implementation. This project is intended to advance four goals: expand translational science capacity in the region to support adaptation; improve regional climate-sensitive conservation decision making; disseminate climate knowledge through conservation networks in the region; and develop both a comprehensive evaluation of the project and a training curriculum for future personnel intending to engage in this type of work. The project will prototype and develop a model for expanding the translational climate science capacity needed to move ecosystem management beyond vulnerability assessments and into on-the-ground decision making for adaptation to climate variability and change.



### DELIVERABLES

1) Publication – Meadow, A. and J. Brugger. 2015 (accepted). Lessons from First Generation Climate Science Integrators. *Bulletin of the American Meteorological Society*.

2) Presentations – Brugger, J. and G. Garfin. 2015. Building the Capacity for Climate Services: Best Practices for Next Generation Climate Science Integrators. 2015 American Meteorological Society Annual Meeting. Phoenix, AZ, January 2015.

Garfin, G., J. Brugger, E. Gordon, J. Barsugli, I. Rangwala, W. Travis, K. Clifford, and A. Meadow. 2015. Building the Capacity for Climate Services: Best Practices for Next Generation Climate Science Integrators. 2015 RISA Program Annual Meeting. Charleston, SC, January 2015.

Garfin, G., J. Brugger, E. Gordon, J. Barsugli, I. Rangwala, W. Travis, K. Clifford, and A. Meadow. 2015. Building the Capacity for Climate Services: Best Practices for Next Generation Climate Science Integrators. CLIMAS Colloquium. Tucson, AZ, May 2015.

**Other Funding Sources:** NOAA Climate Program Office

# Areas of Focus: Decision Support

## Southeast Arizona Agricultural Weather and Climate Working Group

**CLIMAS Investigators:** M. Crimmins, J. Weiss

**Research Collaborators:** Univ. of Arizona — Cooperative Extension; NOAA National Weather Service, Tucson

University of Arizona Cooperative Extension and the National Weather Service (NWS) in Tucson have developed a working group focused on engaging the agricultural community of Southeast Arizona. The working group is assessing information needs, providing training opportunities and technical support, as well as conducting applied research and developing new and enhanced decision support tools. Main activities have included several training and needs assessment workshops, the development and maintenance of a listserv with more than 40 subscribers, and the development of new NWS forecast information visualizations and interfaces focused on frost and freezing events.

### DELIVERABLES

1) Publication – Crimmins, M. 2014. *Tracking Climate and Drought Across Southeast Arizona*. Farm and Ranch Weather and Climate Workshop. Willcox, AZ: University of Arizona Cooperative Extension and NOAA National Weather Service.

2) Workshops – Farm and Ranch Weather and Climate Workshop. Willcox, AZ, June 2014. About 25 attendees, including local growers and resource managers. Workshop evaluations indicated that most attendees learned about new tools and resources available online to help them track drought and identify freezing event risks. <http://cals.arizona.edu/climate/ws/seaz2014.html>

Planning for and Managing Frost and Freeze Events using Weather and Climate Information. Willcox, AZ, November 2014. A follow-up to the initial workshop in June 2014. Ten attendees, including orchard and vineyard owners, discussed the need for different types of frost and freeze forecasting tools. This led to the development of point forecast matrix tool (by NWS) that connected observations from the Arizona Meteorological Network stations to try and improve minimum temperature observations near existing agricultural areas.

**Other Funding Sources:** U.S. Dept. of Agriculture Regional Climate Hub

## Exploring the Use of Climate and Remote Sensing Data to Support Drought Monitoring Across the Southwest U.S.

**CLIMAS Investigators:** M. Crimmins, J. Weiss

**Research Collaborators:** W. van Leeuwen, S. Marsh (Univ. of Arizona — School of Natural Resources and Environment); Univ. of Arizona — College of Agriculture and Life Sciences (web design)

Drought is a complex phenomenon that can vary widely over space due to precipitation patterns and in time due to lagging impacts in slowly varying systems. These factors are magnified in the semiarid Southwest U.S., where extreme interannual climate variability, topography, and highly localized precipitation patterns (e.g., monsoon season thunderstorms) create highly varying hydroclimatic patterns in both space and time and subsequent drought impacts. Current climate monitoring networks across Arizona and New Mexico struggle to capture this variability and accurately portray potential drought conditions.

Complementary datasets, like remote sensing greenness, used in conjunction with existing climate data, offer the potential to monitor drought conditions across large landscapes with sparse monitoring networks. Several efforts, including online geovisualization tools to access raw normalized-difference vegetation index (NDVI or greenness) data and more formalized remote sensing-based drought monitoring tools like VegDRI, have been developed over the past decade. A new effort supported by a recent NOAA-SARP/NIDIS grant spurred the development of tool called DroughtView, which takes a slightly different approach in combining cutting-edge online geovisualization tools with derived remote sensing products targeted at detecting drought conditions. DroughtView builds on the success of its precursor, RangeView, which was developed with guidance from agriculturists and resource managers who need environmental monitoring data. The tools in DroughtView are used to monitor biweekly changes in land surface greenness conditions as a proxy for drought impacts at very fine spatial scales across the Southwest U.S..

### DELIVERABLES

1) Website – DroughtView <http://droughtview.arizona.edu> 2) Publication – Crimmins, M. 2014. *DroughtView: New Tools for Monitoring Drought across Arizona*. Arizona Governor's Drought Interagency Coordinating Group. Phoenix, AZ: Arizona Dept. of Water Resources. 3) Presentation – Hartfield, K. et al. 2014. DroughtView: Satellite Based Drought Monitoring and Assessment. American Geophysical Union Fall Meeting. San Francisco, CA, December 2014.

**Other Funding Sources:** NOAA National Integrated Drought Information System (NIDIS); NOAA Sectoral Applications Research Program (SARP)



## Climate and Weather Services for Disaster Management: A FEMA, NWS, and CLIMAS Collaboration

**CLIMAS Investigators:** M. Crimmins, Z. Guido, A. Meadow, J. McLeod

**Research Collaborators:** Federal Emergency Management Agency – Region 9; NOAA National Weather Service – Western Region

The Federal Emergency Management Agency (FEMA) plays a critical role in helping land, water, and coastal managers prepare for and respond to diverse weather and climate-driven extreme events. Challenges to accessing, interpreting, and disseminating diverse climate and weather (C&W) information, however, limit FEMA's use of this information, which can impede pre-positioning resources in high-risk areas, delay advanced warnings, and spur misunderstanding. Strategic partnerships that link information producers and consumers and provide opportunities for co-developing useful C&W information can help agencies like FEMA better fulfill their mandate to safeguard life and property. This project examines the process of developing strategic partnerships, communication strategies, and relevant C&W information to support FEMA's hazards monitoring efforts in Arizona, Nevada, and California. This study examines the end-to-end process of decision support and will be conducted within a framework advocated by the National Research Council. This includes: assessing FEMA's C&W information needs and gaps; coproducing a decision-support tool; and measuring impacts, successes, and limitations of the decision-support tool, engagement process, and partnership. The objectives are to better understand how to provide climate services and develop strategies that seamlessly transition from research to operations, while assessing the role of 'boundary organizations' (e.g., RISAs) in developing and mediating partnerships that advance climate services and long-term adaptation efforts.

### DELIVERABLES

1) Decision-Support Tool – Development of a climate dashboard that presents historical hydroclimate risk, current climate conditions, and information about future climate. Currently, NWS is writing monthly climate narratives that describe the climate context and refer to the images; the FEMA watch office is viewing the dashboard monthly. <http://www.climas.arizona.edu/content/fema-dashboard-2>

2) Presentation – Crimmins, M. 2015. Climate Information for Disaster Management: Bridging the Weather and Climate Timescales. Guest Lecture for Flood Hydrometeorology & Hydroclimatology – Implications for Global Change and Extreme Hydrology, Univ. of Arizona Dept. of Hydrology and Water Resources. Tucson, AZ, April 2015

**Other Funding Sources:** NOAA National Weather Service – Western Region Headquarters; Federal Emergency Management Agency

# Building A Regional Climate Database: Applications For Research, Collaboration, and Public Engagement - Integrating Climate Data into Ecological Analysis, Monitoring, and Restoration

**CLIMAS Investigators:** B. McMahan, M. Crimmins

**Research Collaborators:** Borderlands Restoration L3C; Hummingbird Monitoring Network; U.S. National Park Service

Researchers are collaborating with regional ecological analysis, monitoring, and restoration groups to facilitate their use of climate data in their regular operations and in their long-term planning/analysis. The impact of climate variability and change, especially as temperature and precipitation regimes shift (resulting in differing time of onset for spring, reduced snowpack, etc.), necessitates a better understanding of these shifts and the implications these changes have for practices of ecological management and restoration.

## DELIVERABLES

1) Presentation – McMahan, B. 2015. Building a Regional Climate Database: Applications for Research, Collaboration, and Public Engagement. American Meteorological Society Annual Meeting. Phoenix, AZ, January 2015. Part of invited session on citizen science.



## TreeFlow Transition

**CLIMAS Investigators:** C. Woodhouse, R. Brice, B. McMahan

**Research Collaborators:** M. Price, D. Archuleta (Univ. of Arizona – Institute of the Environment)

TreeFlow (<http://treeflow.info>) is a comprehensive web resource on tree-ring reconstructions of streamflow and climate for the western U.S., providing access to data for 70 streamflow reconstructions as well as information on data development and applications. While the primary users of streamflow reconstructions are water resource professionals, people in many other sectors and disciplines may find the data useful. TreeFlow is a collaborative effort between two RISA programs, CLIMAS and the Western Water Assessment at the University of Colorado.

The TreeFlow website has been housed on a server at the University of Arizona but the web master, Jeff Lukas of WWA, expressed the desire to step down from this responsibility in the summer of 2013. To make updating easier, researchers decided to move the current Treeflow set of web page to a Drupal platform. The goal of this CLIMAS project has been to make that transition.

**Other Funding Sources:** NOAA – National Climatic Data Center, Paleoclimatology Program; NOAA – National Integrated Drought Information System



# Areas of Focus: Drought

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

**CLIMAS Investigators:** M. Crimmins, D. Ferguson, C. Woodhouse, A. Meadow, R. Brice

**Partners:** Hopi Dept. of Natural Resources; Navajo Nation Dept. of Water Resources

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



## Planning for Drought in the Warming and Drying Southwest: Developing a Suite of Drought Indicators to Support Tribal Decision Making in the Four Corners

**CLIMAS Investigators:** D. Ferguson, M. Crimmins, A. Masayesva

**Partners:** Hopi Dept. of Natural Resources

The goal of this project is to work with the Hopi Tribe's Dept. of Natural Resources (HDNR) to develop a set of drought indicators and approaches for collecting, analyzing, and utilizing the data needed to support each indicator. In addition to indicators that rely on available temperature and precipitation data, we hope to develop a complementary suite of indicators that utilizes drought impacts information the HDNR has begun to collect. The integrated suite of indicators and processes to support monitoring them will: provide the foundation for revisions to the Hopi Tribe's current drought management and response plan; result in a new stream of locally-derived data and information that could provide input to national drought products like the U.S. Drought Monitor; and be the backbone of a system that would provide local, regional, and national decision makers better insight into developing drought conditions before an event reaches critical levels.

### DELIVERABLES

1) Publication – Ferguson, D. 2015. Transdisciplinary Climate Research to Support Decision Making. Ph.D. dissertation. The University of Arizona - School of Geography and Development.

**Other Funding Sources:** NOAA National Integrated Drought Information System (NIDIS); NOAA Sectoral Applications Research Program (SARP)

### DELIVERABLES

1) Publications – Three issues of the Quarterly Hopi Drought Status Report. Published in June, September, and December 2014 by Hopi Dept. of Natural Resources. Provided content and maps for each report.

2) Presentations – Crimmins, M. 2014. Rain Days to Dry Spells: Exploring New Ways to Track Drought Across the Southwest U.S. 11th RISE Symposium (Research Insights in Semiarid Ecosystems). U.S. Dept. of Agriculture Agricultural Research Service and The University of Arizona. Tucson, AZ, October 2014.

Brice, R., C. Woodhouse, and M. Crimmins. 2014. Understanding Sub-annual Tree-ring Climate Records and the Impacts of Climate Extremes in the Four Corners Region, USA. Association of Pacific Coast Geographers Meeting. The University of Arizona School of Geography and Development. Tucson, AZ, September 2014.

Woodhouse, C., R. Brice, M. Crimmins, D. Griffin, H. Faulstich, and D. Ferguson. 2014. Three-Season Hydroclimatic Variability from Tree Rings in the Four Corners Region, USA. Association of American Geographers Annual Meeting. Tampa, FL, April 2014.

Crimmins, M. 2014. Rain Days to Dry Spells: Exploring New Ways to Track Drought Across the Southwest U.S. UA Science Cafe - Downtown Science Series. The University of Arizona College of Science. Tucson, AZ, December 2014.

**Other Funding Sources:** NOAA National Integrated Drought Information System (NIDIS); NOAA Sectoral Applications Research Program (SARP); NASA Space Grant

# Areas of Focus: Economics & Livelihoods

## Sectoral Impacts of Drought and Climate Change

**CLIMAS Investigator:** G. Frisvold

**Research Collaborators:** K. Konyar (California State Univ., San Bernardino – Dept. of Economics); A. Kerna (Univ. of Arizona – Dept. of Agricultural and Resource Economics); R. Bark (Univ. of Leeds – School of Earth and Environment); K. Flessa (Univ. of Arizona – Dept. of Geosciences); S. Dall’erba (Univ. of Illinois – Dept. of Agricultural and Consumer Economics)

**Partners:** National Parks Conservation Association; U.S. Bureau of Reclamation; Central Arizona Project; Cotton Incorporated; Arizona Agri-Business Council; Yuma County Water Users’ Association; Greater Yuma Economic Development Corporation; Arizona House of Representatives, Agriculture and Water Committee; Arizona Farm Bureau; Wellton-Mohawk Irrigation District; Sonoran Institute; Environmental Defense

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. In response to frequent stakeholder requests, the project examines how water transfers would affect the local economies or rural, water-exporting communities. The project examines how drought and climate change would affect acquisition of water for environmental restoration. It also considers how combining agronomic information with seasonal weather forecasts can assist the use of option contracts to reduce water supply risks.

### DELIVERABLES

1) Publications – Bark, R., G. Frisvold, and K. Flessa. 2014. The role of economics in transboundary restoration water management in the Colorado River Delta. *Water Resources and Economics* 8:43-56. This article illustrates the potential of fundamental economic concepts (opportunity cost, marginal analysis, and Pareto-improving compensation) in developing options to provide ecological restoration flows to the Colorado River Delta. <http://www.sciencedirect.com/science/article/pii/S2212428414000516>

Colby, B., G. Frisvold, and M. Mealy. 2015. Managing Climate Risks through Water Trading. In BurnettK., et al (eds.). *Routledge Handbook of Water Economics and Institutions*. London: Routledge. This chapter examines the potential for voluntary water trading and improved forecasting to mitigate water supply risks from climate risk in the Lower Colorado River Basin.

Frisvold, G. 2015. The Economic Contribution of Agriculture in Yuma County. In Noble, W. (ed.). *A Case Study in Efficiency – Agriculture and Water Use in the Yuma, Arizona Area*. Yuma, AZ: Yuma County Agriculture Water Coalition. This chapter applies input-output analysis to both direct and indirect contributions of agriculture to Yuma’s economy, including output, value added, and jobs. Stakeholders in Yuma (both agriculture and local government officials) are concerned that drought and Colorado River shortages will increase pressure to alter property rights to water in Yuma, negatively affecting agriculture and the county economy as a whole. This work was in direct response from stakeholder requests for analysis to respond to U.S. Bureau of Reclamation planning documents. <https://wrrc.arizona.edu/case-study-in-efficiency>

2) Podcast – Participated in the *CLIMAS 1075’ – Shortage on the Colorado River* podcast. Episode 2: Stressors on the River (B. Colby, G. Frisvold, and K. Morino). July 21, 2014. The podcast discussed water supply and demand in the Colorado River Basin and explored how stressors on the basin may change over time as well as how these changes may affect management and behaviors across the Southwest. <http://www.climas.arizona.edu/podcast/1075-shortage-colorado-river-ep-2-stressors-river>

3) Blog – Published a guest blog *Exaggerated Impacts of Unrealistic Water Shortages* (with C. Howe (Univ. of Colorado), F. Ward (New Mexico State Univ.), and G. Taylor (Univ. of Idaho) on John Fleck’s water blog JFLECK at INKSTAIN. The post was a critique of the report *The Economic Importance of the Colorado River to the Basin Region*, pointing out methodological flaws and nonsensical results. <http://www.inkstain.net/fleck/2015/03/exaggerated-impacts-of-unrealistic-water-shortages/>

4) Workshop – Helped organize and moderate a panel presentation on climate, drought, and water at the February 13, 2015, meeting of the Ag 100 Council in Yuma. The Ag 100 Council is a group of state agribusiness leaders. Panelists included G. Garfin (CLIMAS), R. Glennon (Univ. of Arizona – College of Law), and G. Walker (Arizona Dept. of Water Resources). The Ag 100 Council members have many questions and concerns about future Colorado River shortages and how that might trigger policy changes that would negatively affect them.

5) Service – Participated in a May 14, 2015, workshop organized by the Water Funder Initiative, the William and Flora Hewlett Foundation, the Walton Family Foundation, and the S.D. Bechtel, Jr. Foundation, hosted by the Kyl Center at Arizona State University. The leaders of the initiative sought input from 10 to 12 of the field’s top experts for a workshop focused on the situation and perspectives in the Lower Basin of the Colorado River. A major goal was to solicit input on where philanthropic organizations could play the most useful roles in solving western water management problems.

6) Media – Radio: Participated in a radio panel discussion for *High Country News’* Sound Table program on April 8, 2015 (with J. Overpeck and P. Mulroy). The program, called “Are we in a megadrought, and if so how do we secure a well-watered future for the American West?” was aired by NPR affiliates and other community radio stations in western Colorado, southern Utah, southern Nevada, and northern Arizona. <http://azhydrosoc.org/water-in-the-news/>

**Other Funding Sources:** U.S. Geological Survey; U.S. Bureau of Reclamation; U.S. National Park Service; Cotton Incorporated; Yuma County Arizona Cooperative Extension





## Arizona Business Resilience Initiative - An Initiative to Support Arizona's Business Community in Managing Climate Risk

**CLIMAS Investigators:** B. McMahan, G. Owen

**Research Collaborators:** A. Gerlak (Univ. of Arizona – Udall Center for Studies in Public Policy); A. Barnhart (Univ. of Arizona – Renewable Energy Network); J. Weston (Univ. of Arizona – Eller School of Management; School of Natural Resources and the Environment)

**Partners:** Tucson Electric Power

Arizona has experienced significant environmental, economic, and demographic changes over the last 50 years. General trends in climate, along with seasonal decadal variability (e.g., drought, flooding), impose cascading and interrelated impacts across multiple sectors (e.g., business, transportation, energy, infrastructure, etc.). Businesses are already experts at managing risk, but they face new challenges in anticipating these cascading effects linked to future climate-related impacts and associated changes in water availability, more severe/longer heat waves, and higher drought and flood risks.

The Arizona Business Resilience Initiative (ABRI) is focused on developing a methodology for assessing business opportunities and managing risks to operations associated with climate change and climate variability. Researchers will work with business partners to determine the most probable impacts on the company's operations and projections due to climate change and what actions can be taken to anticipate or mitigate these risks or position the company to take advantage of new opportunities that anticipate and adapt to climate change.

**Other Funding Sources:** Univ. of Arizona – Office of Research and Discovery; Univ. of Arizona – Senior Vice President for Research

## Using Critical Thresholds to Customize Climate Projections of Extreme Events to User Needs and Support Decisions

**CLIMAS Investigators:** G. Garfin, B. McMahan

**Research Collaborators:** A. Petersen (Adaptation International); M. Shafer (Southern Climate Impacts Planning Program); K. Hayhoe (ATMOS Research); K. MacClune (Institute for Social and Environmental Transition)

**Partners:** City of Boulder, CO; City of Miami, OK

Many communities are already vulnerable to extreme events, and many of these vulnerabilities will increase with climate change. Identifying and better understanding critical thresholds for extreme events is key to developing effective community responses to climate change. In this project, researchers will test a methodology for using a participatory process to define critical thresholds for extreme events and use these thresholds to customize climate projections to community--specific needs. This project brings together Adaptation International, CLIMAS and SCIPP, two of NOAA's RISA programs, ATMOS Research, and ISET International to address this critical need.

**Other Funding Sources:** NOAA Sectoral Applications Research Program (SARP)

## Climate Mitigation and Agriculture: Public Policy Education

**CLIMAS Investigators:** G. Frisvold, G. Camara, N. Puarattana-aroonkorn

**Research Collaborators:** B. Hurd (New Mexico State Univ. – Agricultural Economics and Agricultural Business); K. Konyar (California State Univ., San Bernardino – Dept. of Economics)

**Partners:** Cotton Incorporated; National Cotton Council; Tohono O’odham Nation

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 to examine how state resource endowments affect policy development and resource use. It also examines strategies to sequester carbon or reduce carbon emissions.

### DELIVERABLES

1) Presentations – Frisvold, G. 2015. Climate Policy as Water Policy: Water Quality & Conservation. The University of Arizona College of Law Environmental Breakfast Club. Tucson, AZ, February 2015.

Frisvold, G. 2015. Energy Production on and near Agricultural Lands: A Threat, an Opportunity ...or Both? National Land Conference. Tucson, AZ, March 2015. This was a presentation with a question and answer session for about 25 real estate professionals.

**Other Funding Sources:** Cotton Incorporated

## Colorado River Research Group

**CLIMAS Investigators:** J. Overpeck, B. Colby

**Research Collaborators:** R. Adler (Univ. of Utah – Law); K. Flessa (Univ. of Arizona – Geosciences); D. Kenney (Univ. of Colorado – Western Water Policy Program); D. Lettenmaier (Univ. of California Los Angeles – Geography); L. McDonnell (Univ. of Colorado – Law); d J. Schmidt (Utah State Univ. – Stream Geomorphology); B. Udall (Colorado State Univ.); R. Waskom (Colorado State Univ. – Colorado Water Institute)

The Colorado River Research Group is a team of 10 scholars whose work focuses on the Colorado River Basin. This group provides information on economic tools and potential responses to climate effects on water supply and demand. It is a self-directed team that provides non-partisan expertise on Colorado River science, law, and policy. <http://www.coloradoriverresearchgroup.org>

### DELIVERABLES

1) Publications – Colorado River Research Group. 2014. *Charting A New Course For The Colorado River: A Summary Of Guiding Principles*. Summary Report. [http://www.coloradoriverresearchgroup.org/uploads/4/2/3/6/42362959/crrg\\_summary\\_report\\_1\\_updated.pdf](http://www.coloradoriverresearchgroup.org/uploads/4/2/3/6/42362959/crrg_summary_report_1_updated.pdf)

Colorado River Research Group. 2014. *The First Step In Repairing The Colorado River’s Broken Water Budget*. Technical and Summary Reports. [http://www.coloradoriverresearchgroup.org/uploads/4/2/3/6/42362959/crrg\\_guiding\\_principles.pdf](http://www.coloradoriverresearchgroup.org/uploads/4/2/3/6/42362959/crrg_guiding_principles.pdf)

Colorado River Research Group. 2015. *The Case for Conservation*. Policy Report. [http://www.coloradoriverresearchgroup.org/uploads/4/2/3/6/42362959/crrg\\_conservation\\_paper\\_051215.pdf](http://www.coloradoriverresearchgroup.org/uploads/4/2/3/6/42362959/crrg_conservation_paper_051215.pdf)



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

**CLIMAS Investigators:** G. Frisvold, T. Bai

**Partners:** Yuma County Water Users’ Association; Arizona Small Grains Research and Promotion Council

This project examines the roles that water management information and irrigation technologies play in agricultural adaptation to climate variability and change across the 17 westernmost U.S. states. Issues addressed include farmer demand for different sources of public and private water management information, adoption of scientific methods and use of electronic media to schedule irrigation, and how climate affects choice of irrigation technologies. The project uses statistical analysis to examine how factors such as farm size, water costs, and drought affect demand for water management information. For Arizona, the project examines trends in agricultural water management, investments in irrigation improvements, and water productivity (e.g., agricultural output per unit of water applied, or “crop per drop”).

### DELIVERABLES

1) Media – Simons, A. and G. Frisvold. 2014. Sustainability of Desert Grain Production Is an Emerging Factor in Customers’ Buying Decisions. Arizona Grain Research and Promotion Council Annual Newsletter. Fall 2014. This op-ed article discussed the challenges of developing “water footprint” and “sustainability” measures for water use in the desert Southwest.

2) Presentation – Frisvold, G. 2015. Sustainable Wheat Production: What Does It Mean? How is It Measured? The National Pasta Association Annual Meeting. Phoenix, AZ, March 2015. More food processing companies are adopting their own environmental standards based on carbon footprints and water footprints. The purpose of the talk was to educate grain producers and food industry executives about different sustainability measures used in private industry and what public data say about grain production sustainability.

**Other Funding Sources:** U.S. Dept. of Agriculture – National Agricultural Statistics Service; U.S. Dept. of Agriculture – Economic Research Service; U.S. Bureau of Reclamation

# Areas of Focus: Education and Evaluation

## RISA: An Organizational Ethnography

**CLIMAS Investigator:** A. Meadow

The RISA program was founded in 1995 as an experiment in the delivery of climate information to decision makers. This project applies organizational ethnographic methods to develop a comprehensive history of the program and a description of its structure and function. The 20-year anniversary of the RISA program is an excellent time to reflect upon how RISA was created, how it has developed, and what other boundary and climate service organizations can learn about how to structure their programs to optimize climate service delivery, collaborative knowledge development, and learning within the organizations.

Understanding how the broader RISA program was founded, how it has developed over the last 20 years, and how it currently functions can provide us with valuable insights into how to build and maintain other climate services or climate-focused boundary organizations.

## “Making the Connection between Science and Decision Making” Graduate Seminar

**CLIMAS Investigators:** C. Woodhouse, D. Ferguson

Scientific knowledge can be critical for dealing with complex, socially relevant environmental issues. However, a large portion of science is ultimately not used to inform decision making surrounding these issues because there is often a mismatch between the types and format of information available and what is useful for these potential consumers. Related to this confounding incongruity, there is often a fundamental lack of two-way communication between scientists and decision makers. This seminar, aimed at graduate students from any relevant discipline, explores concepts at the intersection between environmental science and decision making, including scientific information supply and demand, boundary organizations, coproduction of knowledge, and knowledge networks, as well as recognition of the political context for decision making. It also includes practical aspects of two-way communication to explore the ways in which exchanges take place between scientists and decision makers who can include resource management professionals, planners, policymakers, NGOs, and the general public.

### DELIVERABLES

- 1) Presentation – Woodhouse, C. 2015. Connecting Environmental Science and Decision Making – Graduate Certificate Program. RISA Annual Meeting. Charleston, SC, January 2015. .

**Other Funding Sources:** Univ. of Arizona – School of Geography and Development



## CLIMAS Project and Program Evaluation (2012–2017)

**CLIMAS Investigators:** G. Owen, D. Ferguson, B. Colby, A. Comrie, M. Crimmins, D. DuBois, G. Frisvold, G. Garfin, B. McMahan, J. Overpeck, M. Wilder, C. Woodhouse

CLIMAS, like RISA program, has a primary goal of providing relevant climate-related research to support decision making in our region. A fundamental, though frequently overlooked, element of this type of socially engaged research is evaluation of the program and its constituent projects to understand whether we effectively connect climate science with decision makers; learn about what integrative activities work and why; demonstrate successes to funding agencies, stakeholders, and the public; and improve the overall program. The four elements included in the evaluation are Outreach; Graduate and Undergraduate Training; Advancing Science Knowledge; and Use-Inspired Science and Decision Support.

### DELIVERABLES

- 1) Presentation – Owen, G. 2015. Improving the Science of Science Policy through Climate Services Evaluation. American Meteorological Society Annual Meeting. Phoenix, AZ, January 2015.
- 2) Publication – Ferguson, D., M. Finucane, V. Keener, and G. Owen. In Press. Evaluation to Advance Science Policy: Lessons from Pacific RISA and CLIMAS. *Climate in Context*. New Jersey: Wiley.

# Areas of Focus: Health

## Climate and Health

**CLIMAS Investigators:** A. Comrie, H. Brown, M. Butterworth

**Research Collaborators:** C. Morin (NASA Postdoctoral Program); S. Sen (Univ. of Arizona – Dept. of Computer Science, School of Geography and Development); K. Ernst, Y. Carriere, M. Riehle, K. Walker, J. Lega, R. Barrera (Univ. of Arizona – College of Public Health)

**Partners:** Santa Cruz County Health Dept.; Pima County Health Dept.; Pinal County Health Dept.; Arizona Dept. of Health Services

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 and associated implications for public health, 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.

### DELIVERABLES

1) Publications – Ernst, K., C. Morin, and H. Brown. 2014. Extreme Weather Events and Vector-borne Diseases. In Watson, R., et al (eds.). *Public Health in Natural Disasters: Nutrition, Food, Remediation and Preparation*. Netherlands: Wageningen Academic Publishers.

Brown, H., A. Comrie, J. Tamerius, M. Khan, J. Tabor, and J. Galgiani. 2014. Climate, Windstorms, and the Risk of Valley Fever (Coccidioidomycosis). In *The Influence of Global Environmental Change on Infectious Disease Dynamics*. Washington, DC: The National Academies Press, 266–282.

2) Presentations by H. Brown – 2014. Habitat and Abundance Modeling of West Nile Virus Vector. Society for Industrial and Applied Mathematics Conference on the Life Sciences. Charlotte, NC, August 2014.

2014. Climate Change and You(r Health Arizona). Univ. of Arizona Environment Science Café. Tucson, AZ, October 2014.

2014. Challenges and Spatial Modeling of Vector-Borne Disease Surveillance Data. Symposium on Arid Lands, Food Security, and Health. Tucson, AZ, October 2014.

2014. Climate Change and Health. Wilderness Medical Society Annual Conference.

**Other Funding Sources:** On the Edge: Dengue and Climate. Leveraged project housed in Univ. of Arizona's College of Public Health. With co-PIs K. Ernst, Y. Carriere, M. Riehle, and K. Walker; Simulation Modeling of Public Health Interventions on Dengue Vector Abundance. Leveraged project housed in Univ. of Arizona's College of Public Health. With PI H. Brown, and mentors J. Lega, A. Comrie, and R. Barrera.



S. ELLIS

## Air Quality and Climate

**CLIMAS Investigators:** D. DuBois, R. Armenta, A. Arredondo, E. Smith, Y. Zhou

**Research Collaborators:** M. Flores, M. Stoval, S. Engle, M. Bleiweiss, M. Bean, R. Duran (New Mexico State Univ. - Plant and Environmental Sciences); C. Rincon (Environmental Protection Agency - Region 6); R. Fitzgerald, T. Gill (Univ. of Texas El Paso); V. Etyemezian, G. Nikolich (Desert Research Institute); I. Kavouras (Univ. of Arkansas Medical Sciences); J. Flores Marguez (Univ. Autonoma de Ciudad Juarez); M. Baca, R. Bates (New Mexico Environment Dept. –Air Quality Bureau); G. Tarín Torres (SEMARNAT-Chihuahua); D. Hadwiger, Amy Estelle (New Mexico Dept. of Transportation); Procuraduría Federal de Protección al Ambiente

**Partners:** City of Las Cruces; City of Silver City; NOAA-NWS Albuquerque, Santa Teresa, and El Paso Weather Forecast Offices; U.S. Army Research Laboratory-White Sands Missile Range; New Mexico Dept. of Transportation; U.S. Bureau of Land Management; U.S. Forest Service; The Joint Advisory Committee for the Improvement of Air Quality in El Paso del Norte; and Agro Cultura Empresarial S.A. de C.V.

Dust storms in the Southwest U.S. and northern Mexico continue to be a serious health and safety issue. This project aims to locate the sources of dust that have impacted people in southwestern New Mexico, northwestern Chihuahua, and west Texas. Researchers continued surveillance of dust storms and determined the latitude and longitude of each event. To better understand the characteristics of the land surface from where the dust emission occurs, researchers identified more than 2,000 locations responsible for a dust plume as seen in satellite imagery and are in the process of understanding the state-of-the-land surface at those locations. Researchers also have started work to construct a synoptic climatology of these dust storms to increase their ability to forecast these events.

### DELIVERABLES

- 1) Blog Posts – Several posts on the NM Border Air Quality Blog (<http://nmborderaq.blogspot.com/>) documenting dust events that impacted New Mexico, northwestern Chihuahua, and west Texas.
- 2) Maps – Updated locations and created several maps for the New Mexico Environment Dept. and Dept. of Transportation. Maps included poster-sized printouts of MODIS satellite imagery of a recent dust event that impacted southern New Mexico.
- 3) Workshops – Climate Change Workshop at the New Mexico Environment Dept. – Summary of findings from the National Climate Assessment and Southwest Climate Assessment. Workshop requested by the Planning Section Chief at the New Mexico Air Quality Bureau. Santa Fe, NM, January 2015. Approximately 20 in attendance at the meeting and five online attendees.  
  
13<sup>th</sup> Annual Climate Prediction Applications Science Workshop (CPASW) – co-host with NOAA Climate Program Office and U.S. Dept. of Agriculture Southwest Climate Hub. Las Cruces, NM, March 2015. About 80 people attended the workshop. <http://cpasw.nmsu.edu/>
- 4) Presentations – DuBois, D. and S. Engle. 2015. Lessons Learned in Forming and Maintaining Partnerships in Climate Literacy in New Mexico. 13<sup>th</sup> Annual Climate Predictions Applications Science Workshop. New Mexico State University. Las Cruces, NM, March 2015.  
  
Arredondo, A. and D. DuBois. 2015. Sensor Network Data Collection and Monitoring for Climate Scientists. 13<sup>th</sup> Annual Climate Predictions Applications Science Workshop. New Mexico State University. Las Cruces, NM, March 2015.
- 5) Videos – Videos published on the New Mexico Climate Center's YouTube channel to support outreach on climate, air quality, and projects at the New Mexico Climate Center (<https://www.youtube.com/NMClimate>). Additional videos produced for Master Gardener program to demonstrate how to access data sources discussed during climate workshops.

**Other Funding Sources:** NOAA National Weather Service; U.S. Environmental Protection Agency Border 2012; New Mexico Dept. of Health

## Vulnerability Assessment for Vector-borne Diseases and Valley Fever in Arizona

**CLIMAS Investigators:** H. Brown, M. Wilder

**Research Collaborators:** Univ. of Arizona – Geographic Information Systems Technology Programs; Arizona Dept. of Health Services – Center for Disease Control

In support of the Arizona Dept. of Health Services Building Resilience Against Climate Effects (BRACE) program, CLIMAS researchers are conducting a vulnerability assessment for Arizona residents to climate change-related impacts from vector-borne diseases and valley fever.



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