



## The Climate Assessment for the Southwest

June 1, 2017–May 31, 2018

The work highlighted in this report is supported by the National Oceanic and Atmospheric Administration’s Climate Program Office through grants NA12OAR4310124 and NA17OAR4310288.

More information: Daniel Ferguson, Program Director  
[dferg@email.arizona.edu](mailto:dferg@email.arizona.edu)  
 (520) 626-1779

### Table of Contents

---

2017-2018 CLIMAS Team	2
New Areas of Focus and Partnerships	2
Regional Climate Services	6
Program Impact – Evaluation Efforts	7
Building Adaptive Capacity in the Southwest	7
2017-2018 CLIMAS Highlight	8
Selected Research Findings	9
Outreach Activities	10
Publications Highlights	11
Selected Applications of CLIMAS Work	12
Economic Impact	13
Contributions to the NIDIS Regional Drought Early Warning System	14
Data Management Plan	14
Continuing CLIMAS Projects	
Adaptation & Vulnerability	15
Decision Support	16
Drought	17
Economics & Livelihoods	17
Education & Training	18
Health	19
Appendix: 2017-2018 Publications	21

## 2017-2018 CLIMAS Team

---

**Principal Investigators:** Daniel Ferguson (Lead PI), Heidi Brown, Michael Crimmins, George Frisvold, Connie Woodhouse

**Co-Principal Investigators:** Bonnie Colby, David DuBois, Gregg Garfin, Ladd Keith, Ben McMahan, Alison Meadow, Gigi Owen, Stephanie Rainie, Jeremy Weiss

**Senior Personnel:** Sarah LeRoy, Mitch McClaran, Craig Rasmussen, Marcel Schaap, Margaret Wilder

**Student Researchers:** Antonio Arredondo, Leah Bishop, Patrick Bunn, Hsin-I Chang, Sarah Frederick, Jaylen Fuentes, Zahra Ghodsizadeh, Josue Gutierrez, Chengyang Hu, Rowan Isaacs, Gabe McGowan, Trevor McKellar, Octavio Nayares, Isaac Palomo, Xin Qiao, Genesis Rodriguez, Marie-Blanche Roudaut, Michael Story, Tess Wagner, Xinye Wu, Ryan Young

**Research Affiliates:** Erika Barrett, Merrill Bean, Michael DeAntonio, Stan Engle, Andrea Gerlak, Zack Guido, Martina Klose

**Environment & Society Fellows:** 2017 – Sneha Balakrishnan, Becky Brice, and Danielle Johnson; 2018 – Tamee Albrecht, Sophia Borgias, Stephanie Doerries, Rachel Murray, Marie-Blanche Roudaut

## New Areas of Focus and Partnerships

---

### Evaluating Existing and Developing New Drought Indices using Modeled Soil Moisture Time Series

**CLIMAS Investigators:** M. Crimmins, M. Schaap, C. Rasmussen, D. Ferguson, and T. McKellar

**Project Description:** This project aims to develop long-term (>50 years), daily resolution soil water profile climatologies for several locations across the Southwest. We will assess how seasonality and precipitation timing and frequency relate to monthly precipitation-based drought indices. Cross correlations and time series analyses will be used to assess when and where traditional drought indices align with modeled soil moisture stress. We will use this modeling approach to assess the performance of temperature-based indices and further explore the role of increasing temperatures in driving drought stress across the region. Our initial project study area focuses on the Las Cienegas National Conservation Area, a multi-use, Bureau of Land Management area in Southeast Arizona. We are working in partnership with The Nature Conservancy to develop modeled long-term soil moisture estimates to examine with long-term vegetation monitoring data. Together we will assess the impacts of precipitation variability and temperature changes on vegetation production and mortality and identify optimal drought monitoring metrics.

**Partners:** The Nature Conservancy; US Bureau of Land Management

**Additional Support:** NIDIS—Coping with Drought

### A Colorado River Shortage Declaration: Planning, Responses, and Consequence

**CLIMAS Investigators:** G. Frisvold, X. Wu, and C. Hu

**Project Description:** Based on interstate and international agreements, a Colorado River shortage declaration would reduce surface water deliveries to primarily to Central Arizona, with nearly all the cuts applied to agriculture, representing a 25%-40% reduction in surface water to the region's farms. The US Bureau of Reclamation provides forecasts of the probability of a shortage declaration based on Lake Mead water levels. Little is known about whether early

warning systems are meeting farmers' needs and what a shortage would mean for income, jobs, and groundwater use in rural economies. The study assesses how stakeholder groups currently use Colorado River supply forecasts in decision-making, the contingencies made in the event of a shortage declaration, the economic consequences of a shortage declaration on agriculture and the local economies in central Arizona, and potential impacts of a shortage declaration on groundwater pumping and water levels in central Arizona Active Management Areas.

**Partners:** NOAA—National Climatic Data Center; US Bureau of Reclamation; Arizona Department of Water Resources; University of Arizona—Water Resources Research Center; Maricopa-Stanfield Irrigation District; Central Arizona Irrigation and Drainage District

**Additional Support:** NIDIS—Coping with Drought

### **Impacts of Climate Extremes to Interstate and Local Trucking Industries**

**CLIMAS Investigators:** D. DuBois, A. Arredondo, Z. Ghodsizadeh, J. Fuentes, J. Gutierrez, O. Nayaes, S. Engle, M. Bean, and M. DeAntonio

**Project Description:** Highway transportation forms the basis of our economy, moves goods from place to place, and connects communities. Building on existing partnerships between CLIMAS and state transportation managers from New Mexico and Arizona, we address the impacts of extreme drought and dust storms on our transportation system. Our main goal is to increase driver safety during these events. Our project starts in southwestern New Mexico along Interstate 10 where lives have been lost as a result of dust storms. Our partners include the New Mexico Department of Transportation and trucking companies who are interested in improving the way they handle these dust storms through education and warning. This project will characterize and document the climatic and visual conditions that exist during these storms through interviews, time-lapse camera imagery, and dashboard cameras.

**Partners:** NOAA National Weather Service—Santa Teresa and Phoenix Offices; US Bureau of Land Management—Las Cruces Office; New Mexico Department of Transportation; Mesilla Valley Transportation

**Additional Support:** New Mexico Department of Transportation; NIDIS—Coping with Drought

### **Evaluating the Use of Urban Heat Island and Heat Increase Modeling in Land Use and Planning Decision-Making**

**CLIMAS Investigators:** L. Keith, B. McMahan, M. Story, and T. Wagner

**Project Description:** The impacts of the urban heat island (UHI) are well documented, including increases in heat-related public health issues, stresses on urban ecology, and energy usage to mitigate the higher temperatures. UHI is of particular concern to cities in the Southwest, since it counteracts the cooling that otherwise normally occurs at night. While UHI mapping and modeling has become more sophisticated in recent years, there is still an information gap between the heat maps and models, urban planning and design strategies to decrease heat, and the use of that information in policy decision-making. This study focuses on documenting the current use of urban heat maps and models in communities in Arizona and New Mexico and evaluating best practices and opportunities to increase their usability.

**Partners:** City of Tucson, AZ; Pima Association of Governments; City of Albuquerque, NM; Bernalillo County, NM; City of Phoenix, AZ; City of Las Cruces, AZ; Arizona State University; Trust for Public Land; Green Infrastructure/Low Impact Development Working Group

### **Visualization & Analysis Tools for the North American Monsoon – Integrating Citizen Science Data and Observations**

**CLIMAS Investigators:** B. McMahan, M. Crimmins, P. Bunn, G. McGowan, and H. Chang

**Project Description:** Monsoon precipitation is difficult to forecast and analyze. Daily and seasonal precipitation data are commonly used but other sources, such as citizen science monitoring, could be integrated into a higher resolution and more accurate monsoon assessment framework. Tucson, AZ has dozens of observations through these networks, along with datasets based on radar and weather models. A central monsoon data repository would form a dense network of observations, facilitate innovative visualizations, and offer an unparalleled high-resolution view of regional precipitation patterns. This project tests a process through which southwestern data networks could be combined into an integrated monsoon assessment database.

**Partners:** NOAA National Weather Service—Tucson Office

**Additional Support:** University of Arizona—Office of Research Discovery and Innovation; NOAA National Weather Service—Tucson Office; University of Arizona—College of Agriculture and Life Sciences; University of Arizona—Institute for Energy Solutions

### **Collaborative Research on Environmental Risks and Built Environment in the Borderlands of the Southwest**

**CLIMAS Investigators:** B. McMahan, G. Rodriguez, L. Bishop, and I. Palomo

**Project Description:** Numerous avenues for collaborative research projects and outreach exist in the borderlands region. This project provides a mechanism to develop new research and engagement and to connect CLIMAS expertise to existing project work. This project emphasizes environmental risks and air quality, small scale computing and technology, citizen science monitoring of environmental phenomena, small-scale solar feasibility, and emergent CLIMAS outreach and network development.

**Partners:** NOAA National Weather Service—Tucson Office; Arizona Department of Environmental Quality; Asociación por Revegetación en Ambos Nogales; Sonora Environmental Research Institute; Borderlands Restoration

**Additional Support:** US Environmental Protection Agency Border 2020; University of Arizona—Agnese Nelms Haury Program in Environment and Social Justice

### **Community Climate Profiles**

**CLIMAS Investigators:** A. Meadow, J. Weiss, L. Keith, and S. LeRoy

**Project Description:** Climate change adaptation planning requires decision-makers to envision the future of their communities, and make well-grounded assumptions about economic, demographic, and cultural trends that are likely to affect that vision. However, many communities lack the technical resources to compile and analyze climate data and research findings, thus making the information essentially inaccessible to them. This project produces climate profiles for communities to support their adaptation planning efforts. These profiles include information such as historical/instrumental temperature and precipitation data from 1895–present at scales appropriate to the decisions made within the community of interest, explanations of key climate phenomenon that impact climate and weather in the region, current climate trends, projections of climate change at a regional scale, and a summary of general regional climate impacts. Current climate profiles include the City of Flagstaff, AZ and the Tohono O’odham Nation.

**Additional Support:** Cascadia Consulting, LLC

### **Southwest Tribal Data Summit: Partnering with Southwest Indigenous Communities to Identify Data Challenges, Needs, and Opportunities**

**CLIMAS Investigators:** S. Rainie, D. Ferguson, and S. LeRoy

**Project Description:** Climate monitoring on Native American lands can range from sparse to nearly nonexistent, particularly in some of the remote regions of the Southwest. Inconsistent, irrelevant, and poor quality community health data also limits effective decision-making for Native nations, including decisions related to community climate resilience. Even when data is available, the capacity of an Indigenous community to manage and analyze data may be limited by few staff who are frequently juggling multiple tasks or have little to no background in working with climate data. As Native nations seek to utilize the best available information to build climate resilience and healthy, sustainable communities, issues around data relevance, ownership, access, possession, and control also arise. This project begins to address these issues by convening a multiple day meeting in September 2018 – “Supporting Tribal Data Governance for Community Resilience: A Southwest Indigenous Climate Summit.” This invite-only event will foster discussion about unique issues surrounding Indigenous data sovereignty, tribal data governance, and Indigenous knowledge related to climate resilience efforts within Southwest Indigenous communities.

**Partners:** University of Arizona—Native Nations Institute; US Indigenous Data Sovereignty Network; Colorado State University; University of North Carolina; Albuquerque Area Southwest Tribal Epidemiology Center; Inter Tribal Council of Arizona

**Additional Support:** NIDIS—Coping with Drought

### **Improved Understanding of Climate Variability and Change Relevant to Orchards and Vineyards in Arizona and New Mexico**

**CLIMAS Investigators:** J. Weiss, M. Crimmins, D. DuBois, G. Frisvold, A. Meadow, and M. Roudaut

**Project Description:** Orchards and vineyards are increasingly important to rural economies of the Southwest, but growers of these high-value perennial fruit and nut crops have limited climate information to support critical decisions about selecting sites and cultivars. These crops are particularly sensitive to temperature, but it is unclear how recent warming in the Southwest has affected—and how future anticipated increases in temperature might affect—the climatic conditions important to orchards and vineyards. This project works closely with Arizona and New Mexico Cooperative Extensions and individual farmers to survey a set of orchards and vineyards currently under production to gather information about their siting and cultivars. We will assess the required temperature conditions for the current cultivars, whether these have historically been met, and if they are likely to be met in the coming decades. Using crop insurance indemnity records, we will perform a financial assessment of how site and cultivar selection are functioning in the current regional climate. We will also evaluate the suitability of present-day orchards and vineyards in the context of anticipated increases in regional temperature.

**Partners:** New Mexico State University Cooperative Extension; University of Arizona Cooperative Extension; Yavapai College Viticulture and Enology Program; Verde Valley Wine Consortium

**Additional Support:** NOAA—National Centers for Environmental Information; TopoWx; Verde Valley Wine Consortium; US Geological Survey

## **The Influence of Climate on Lower Colorado Streamflow Variability: Present, Past, and Future**

**CLIMAS Investigators:** C. Woodhouse, D. Ferguson, A. Gerlak, and S. Frederick

**Project Description:** Warming temperatures are an increasingly important control on streamflow and surface water supplies. This has been demonstrated in the upper Colorado River basin, but studies have not yet investigated the impact of temperatures on the streamflow in the lower Colorado River basin (LCRB). In the three major tributaries of the LCRB—the Salt, Verde, and Gila Rivers—snow deposition areas are at lower elevations than in the upper Colorado River basin, and temperature could play a more significant role in mediating how much precipitation ends up as streamflow. An additional factor that has not been fully investigated is the monsoon’s contribution to streamflow and how warming temperatures may affect that contribution. This study evaluates the seasonal climatic components that control surface water supplies in the lower Colorado basin and focuses on the influence of temperature on annual streamflow in recent decades. The project team will identify interested resource management partners in the LCRB who would like to help shape a research agenda that addresses climatic controls on surface water supplies in the lower basin in a way that is relevant to resource management. We will begin dialog in late summer 2018 with a small group (10-12) of potential research partners to identify research questions and develop a collaborative project team that is interested in being engaged at least through the life of the project and potentially beyond.

## **Regional Climate Services**

---

**Arizona:** CLIMAS researchers helped create a rangeland precipitation tracking tool called myRAINge Log. The development of this tool emerged through discussions with ranchers and land managers in central Arizona, who identified their need for an easy way to track precipitation observations across remote rangeland sites. The tool is available online:

<https://myraingelog.arizona.edu>. Crimmins M, M McClaran, J Brugger, D Tolleson, M King, JD Gibbs, and Y Torrey. 2017-present. myRAINge Log: Rangeland precipitation tracking tool. Tucson, AZ. Cyber Communications and Technologies—College of Agriculture and Life Sciences, University of Arizona.

**New Mexico:** CLIMAS Co-PI and New Mexico State Climatologist Dave DuBois provides information on a wide range of topics across the state. This year he gave 11 presentations tailored to specific stakeholder information needs regarding regional climate trends and health impacts. He uses Twitter, Facebook, and YouTube to communicate with people about climate. His activity on Twitter has generated many off-line conversations with the media and spurred several TV and radio interviews about drought, health, and climate change in New Mexico.

**Southwest Region:** The Rio Grande/Bravo region of the southwestern United States and northern Mexico is especially vulnerable to extreme heat. CLIMAS researchers Gregg Garfin and Sarah LeRoy have helped develop a National Integrated Heat Health Information System to increase preparedness and capacity to adapt to extreme high temperatures and heat waves in this region. The project has resulted in a website describing available resources about heat health; a database of people in the region working on heat and health issues; new research and outreach partnerships, including three spin-off research projects; increased neighborhood-level capacity to communicate heat health risks; increased awareness of extreme heat and associated risks by city governments; and improved communication for extreme heat early warning systems.

## Program Impact – Evaluation Efforts

---

In 2012, CLIMAS implemented evaluation as a core component of the program, using a theory-based evaluation framework. Between 2012-2017, CLIMAS investigators identified 23 projects to evaluate. Selection criteria included projects that engaged nonacademic partners and allowed for annual monitoring and data collection. We designed evaluation research plans for each project using a series of action-logic models to articulate how program activities and outputs lead to measurable outcomes. This process included defining contexts, research inputs, expected outputs, short-to-medium term outcomes, and broader impacts. Data measuring progress towards outputs and outcomes were collected via periodic semi-structured interviews with CLIMAS investigators in 2012 (15 interviews), 2014 (12 interviews), and 2017 (11 interviews), and annually through project reports between 2012-2017.

We are currently analyzing evaluation data for program operations and projects between 2012-2017. Emerging results illuminate five core functions that CLIMAS plays in promoting climate resilience for the Southwest, including: a) communicating information and improving climate knowledge; b) convening people and organizations whose interests relate to climate; c) consulting by providing tailored, expert advice and analysis for targeted audiences; d) collaborating with representatives from other academic institutions, and organizations, agencies, and communities outside of academia; and e) training current and future generations of researchers to apply interdisciplinary and transdisciplinary theory in practice. Findings from the 2012-2017 program evaluation will be publicly available in 2019. A new evaluation process began with our new RISA award for program activities conducted between 2017-2022.

## Building Adaptive Capacity in the Southwest

---

This year, CLIMAS investigators responded to several types of climate service needs to help local and regional decision makers prepare and adapt to climate variability and change. Selected examples include:

- Providing guidelines for voluntary, collaborative water trading agreements and designing metrics to evaluate the environmental and ecological impacts of these agreements in the western US. (*Adaptation Strategies for Water and Energy Sectors in the Southwest*)
- Preparing location-specific climate profiles for the City of Flagstaff, AZ and the Tohono O’odham Nation to inform adaptation planning. (*Community Climate Profiles*)
- Expanding research and outreach efforts regarding environmental risk and air quality on the US-Mexico border region. (*Collaborative Research on Environmental Risks and Built Environment in the Borderlands of the Southwest*)
- Partnering with the National Weather Service—Tucson Office to improve monsoon forecasts and information. (*Visualization & Analysis Tools for the North American Monsoon – Integrating Citizen Science Data and Observations*)
- Providing analyses of agricultural water use efficiency and productivity measures due to adaptations adopted by farmers in Yuma County, AZ. (*Adaptation to Climate Variability and Change: Markets, Policy, Technology, and Information*)

- Facilitating quarterly community-based conservation discussions about research and outreach priorities for the lower San Pedro River in Arizona. (*CLIMAS 2016-2017 Assessment – Identifying Emergent Research Priorities and Expanding the Regional Network*)
- Providing sector-specific information to regional agricultural producers tailored to cotton and wheat growers, as well as the dairy industry and feed growers. (*Sectoral Impacts of Drought and Climate Change*)
- Convening an annual workshop for research partners and stakeholders who are working on heat and health issues in the US-Mexico border region. (*Developing Integrated Heat Health Information for Long-term Resilience and Early Warning*)
- Partnering with a local electric utility to inform their long-term planning processes. (*Arizona Business Resilience Initiative – An Initiative to Support Arizona’s Business Community in Managing Climate Risk*)
- Expanding our program’s colloquium series to provide timely discussions based on seasonal climate issues and providing these presentations online—live and archived. (*CLIMAS Colloquium Series*)
- Providing guidance for health workers in Arizona to build resilience against the effects of climate-sensitive hazards. (*Climate and Health Adaptation Monitoring Program*)

## 2017-2018 CLIMAS Highlight

Water supply and drought are constant concerns in the Lower Colorado River Basin. In 2014, the Bureau of Reclamation and Colorado River Basin states and water users implemented the Lower Colorado Region Pilot System Conservation Program to evaluate the potential of water trading agreements to address impacts of long-term drought. Tribal governments, federal and state agencies, and stakeholder groups representing agriculture, urban areas, and the environment have since been exploring and implementing voluntary collaborative agreements to share water rights to address regional environmental risks associated with water and drought. Bonnie Colby’s research team (see *Adaptation Strategies for Water and Energy Sectors in the Southwest*) has been instrumental in developing this pilot program by analyzing the economic outcomes of water-trading agreements and providing guidance to groups who are interested in participating.

Water management agencies and tribal organizations have solicited presentations and workshops from Colby focusing on the potential environmental and economic impacts of water trading. She has helped initiate collaborative agreements between organizations that wish to acquire water rights for the environment and agriculturalists that are willing to trade their water rights. Colby has contributed to developing and implementing a framework to evaluate the environmental and economic impacts of water transactions (see Kendy et al. 2018). Their findings suggest that agreements are an effective approach to address the economic damages that accompany climate-related water supply variability. Colby’s team documented the innovative approaches to water transactions that tribal organizations have developed and analyzed the economic impacts of these approaches in the Basin (see Colby and Young 2018). Through presentations and outreach, she has provided guidance on how to monitor amounts of water flow for the environment that is produced through these agreements. Colby’s team is currently creating a guidebook for organizations interested in creating, implementing, and evaluating these agreements.

## Selected Research Findings

---

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

**CLIMAS Investigators:** G. Frisvold and X. Qiao

More than 60% of planted cotton acres may be abandoned in some US counties, often as a result of extreme drought. Regression analysis shows that irrigation reduces abandonment, but greater crop insurance coverage increases it.

Return flows from agricultural systems—once characterized as an indicator of inefficiency—provide valuable environmental services to the Colorado River Delta ecosystem. Scholars working on the ecological restoration of the Colorado Delta are taking a more nuanced view regarding the ecological benefits of agricultural return flows. Reducing the water diverted for Yuma agriculture and increasing the water taken up by crops means less water is available for ecosystem services. Water practices previously characterized as inefficient actually improve the environment. Ecosystem services also provide economic benefits for the region.

### **Impacts of Climate Extremes to Interstate and Local Trucking Industries**

**CLIMAS Investigators:** D. DuBois, A. Arredondo, Z. Ghodsizadeh, J. Fuentes, J. Gutierrez, O. Nayaes, S. Engle, M. Bean, and M. DeAntonio

As a result of collecting time-lapse camera imagery at one of the dust storm areas on Interstate 10, we have observed driver behaviors during multiple storm events. Based on preliminary analysis, very few drivers slow down or heed the suggestion to pull-aside and wait for the storm to subside before driving through them. We plan on characterizing these reactions of drivers using time-lapse imagery during the most intense dust events.

### **Western Region Climate Services Provider Database**

**CLIMAS Investigators:** B. McMahan

Preliminary analysis of a survey of climate service providers suggest that: a) providers focus on drought, water, and climate/weather information; b) gaps include information about energy, social vulnerability, and human health; and c) climate services provision is frequently more about understanding how to use the data available, rather than knowing what data is available.

### **A Colorado River Shortage Declaration: Planning, Responses, and Consequence**

**CLIMAS Investigators:** G. Frisvold, X. Wu, and C. Hu

Economic returns to agriculture in Central Arizona vary significantly from year to year. Economic impacts of a shortage declaration on the Colorado River also widely vary. Earlier economic analyses conducted by the US Bureau of Reclamation did not account for this variability. Their analyses assumed that the only adaptation that farmers would make would be to fallow their land, however a significant number of producers plan to switch from surface water to groundwater in response to possible curtailment of surface water supplies.

### **Air Quality and Climate**

**CLIMAS Investigators:** D. DuBois, A. Arredondo, Z. Ghodsizadeh, J. Fuentes, J. Gutierrez, O. Nayaes, S. Engle, M. Bean, M. DeAntonio, and M. Klose

We developed a method to identify synoptic patterns associated with dust storms across the Southwest US. Our method was successful for identifying dust storms, however it also identified non-dust events. We found that other variables needed to be included in our analysis for more accurate results. One variable to be included in future analyses is soil moisture.

### **Sectoral Impacts of Drought and Climate Change**

**CLIMAS Investigators:** G. Frisvold, X. Qiao, X. Wu, and C. Hu

Estimated local foods sales and spending in Maricopa County, AZ total in the tens of millions of dollars annually, based upon national averages. Agricultural production within the Gila River Indian Community (part of which is in Maricopa County) generated \$38.4 million in cash receipts in 2017. In this community, 17 of 39 farms had over \$100,000 in annual sales.

## Outreach Activities

---

### CLIMAS Colloquium Series

**CLIMAS Investigators:** All

In 2017, CLIMAS began hosting a colloquium series to highlight seasonal climate topics such as the monsoon and fire season, as well as updates on current CLIMAS projects. The series is broadcast live online and videos of the presentations and discussions are archived on our YouTube channel (<https://www.youtube.com/user/UACLIMAS>). Presentations each have 20-80+ views on YouTube. The mixed live audience presentation/webinar model has proven to be a popular approach. The most highly attended event was about Drought in the Southwest (January 2018). The colloquium series has generated some of our most engaging Twitter posts as well. For example, a tweet about the Fire in the Southwest colloquium generated more than 7200 impressions and 60 engagements. Several colloquia attendees mentioned that they learned about the series because their colleagues retweeted information from the CLIMAS Twitter account.

### The Southwest Climate Outlook

**CLIMAS Investigators:** B. McMahan, M. Crimmins, and D. DuBois

The Southwest Climate Outlook (SWCO) summarizes climate and weather information from disparate sources in nonscientific language, providing more than 1,600 people with timely climate-related information. Since SWCO's inception in 2002, the publication has evolved into a tool for two-way communication with stakeholders and a platform for responding to needs throughout the region. This year we published 12 issues. The most popular issues were published in June and July of 2017 and April and May of 2018 – likely due to their correspondence with the annual monsoon. SWCO continues to be a primary way in which CLIMAS interacts with a larger audience of stakeholders and the general public. <https://www.climas.arizona.edu/swco>

**Additional Support:** NIDIS—Coping with Drought

### Southwest Climate Podcasts

**CLIMAS Investigators:** B. McMahan, M. Crimmins, and Z. Guido

El Niño, the monsoon, increasing temperatures, and dwindling reservoir storage are just a few of the climate-related issues that periodically punctuate the news cycle in the Southwest. CLIMAS scientists discuss these issues in monthly climate podcasts that synthesize information from disparate sources and translate national and global discussions into what they mean for the Southwest. Podcasts receive between 100 and 300 visits to the page (listeners who syndicate the downloads via a podcast app or iTunes are not reflected in these numbers). The podcasts are publicized every month on social media and through our list-serv. They garner the most traffic when another media outlet picks up the content, promotes it, or endorses it to their network. Most popular episodes this year included discussions about: impacts of La Niña in February 2018, recapping the monsoon season in August 2017, and the influence of atmospheric rivers in Southwest precipitation in April 2018. <http://www.climas.arizona.edu/media/podcasts>

**Additional Support:** NIDIS—Coping with Drought

### **Southwest Climate Information Hubs**

**CLIMAS Investigators:** B. McMahan, M. Crimmins, J. Weiss, and G. Garfin

As the El Niño event wound down, the El Niño Hub was updated to become the El Niño Southern Oscillation Hub to capture La Niña outlooks and activity. This pilot process was used as a model to update the Southwestern Climate section of the CLIMAS website for other topical areas of interest, such as drought, monsoon, temperature, and precipitation. Other emergent areas in which these types of hubs would be useful include health and environmental risk. The general public and media contacts were receptive to aggregated information that was focused on timely outreach and in anticipation of an event.

**Additional Support:** NIDIS—Coping with Drought

### **Southwestern Oscillations: News, Information, & Commentary (The CLIMAS Blog)**

**CLIMAS Investigators:** B. McMahan, M. Crimmins, and I. Palomo

Southwestern Oscillations is an ongoing source of engagement with the general public and other scientists/practitioners. It is the hub for news, information, and commentary about CLIMAS research and climate-related issues. This blog is updated regularly to distribute news, updates, and other information on CLIMAS research projects and publications. This year, 44 blog posts were written. <http://www.climas.arizona.edu/blog>

### **The Rio Grande-Bravo Outlook**

**CLIMAS Investigators:** G. Garfin and S. LeRoy

This product provides information about recent climate events and trends, future forecasts, and seasonal outlooks for the Rio Grande-Bravo river basin, a region that incorporates New Mexico and western Texas. The outlook is written in both Spanish and English and was first published in November 2015. It is produced monthly in collaboration with the NOAA Southern Region Climate Services director and the Southern Climate Impacts Planning Program. This year, 12 issues were published. <http://www.climas.arizona.edu/rgbo>

## **Publication Highlights**

---

McAfee SA, GT Pederson, CA Woodhouse, and GJ McCabe. 2017. Application of synthetic scenarios to address water resource concerns: A management-guided case study from the Upper Colorado River Basin. *Climate Services* 8, 26-35. <https://doi.org/10.1016/j.cliser.2017.10.003>.

Results suggest that existing studies may underestimate the degree of uncertainty in future streamflow, particularly under moderate temperature and precipitation changes. The relative severity of future flow projections within a given climate scenario can be estimated with simple metrics that characterize the input climate data and basin conditions. This study was undertaken in collaboration with water resource managers, using a bottom-up approach to identify the range of climate conditions in climate projections that could produce hydrologic conditions of concern.

Frisvold G, C Sanchez, N Gollehon, SB Megdal, and P Brown. 2018. Evaluating Gravity-Flow Irrigation with Lessons from Yuma, Arizona, USA. *Sustainability* 10(5):1548. doi:10.3390/su10051548

Local irrigation districts wanted evaluations measuring the implications of farming adaptations for water conservation and ecological restoration. This paper responds to this need by providing analysis on the role of agricultural return flows for ecological restoration of the Colorado River Delta. Through extensive changes in irrigation technologies, changes in production practices, and investments in irrigation infrastructure, Yuma agriculture shifted from perennial and summer-centric

crop production to winter-centric, multi-crop systems focused on high-value vegetable crops, which has led to improvement in irrigation efficiency and overall water conservation.

Roach M, E Barrett, H Brown, B Dufour, DM Hondula, H Putnam, and B Sosa. 2017. *Arizona's Climate and Health Adaptation Plan*. A report prepared for the United States Centers for Disease Control and Prevention Climate-Ready States and Cities Initiative.

<https://www.azdhs.gov/documents/preparedness/epidemiology-disease-control/extreme-weather/pubs/arizona-climate-health-adaptation-plan.pdf>

This document compiles health adaptation ideas, direction, and activities to help guide Arizona stakeholders in building resilience against the effects of climate-sensitive hazards. The document provides examples of public health related initiatives for individuals and organizations interested in adaptation planning around human health. Several project partners contributed content including: the Maricopa County Department of Public Health; the City of Phoenix, AZ; NOAA—National Weather Service Tucson and Phoenix Offices; and Z Mansion.

McCabe G, D Wolock, G Pederson, C Woodhouse, and S McAfee. 2017. Evidence that recent warming is reducing upper Colorado River Flows. *Earth Interactions* 21:1-14.

<https://doi:10.1175/EI-D-17-0007.1>

Variability in water-year precipitation in the Upper Colorado River Basin (UCRB) explains more of the variability in water-year streamflow than water-year temperature does. However, since the late 1980s, increases in temperature in the UCRB have caused a substantial reduction in runoff efficiency—the ratio of streamflow to precipitation.

Duval D, AK Bickel, G Frisvold, X Wu, and C Hu. 2018. Contribution of Agriculture to the Maricopa County and Gila River Indian Community Economies. *Department of Agricultural & Resource Economics, Cooperative Extension Report*. University of Arizona, Tucson, AZ.

[https://cals.arizona.edu/arec/sites/cals.arizona.edu/arec/files/publications/contrib\\_ag\\_maricopa\\_county\\_GRIC\\_economies.pdf](https://cals.arizona.edu/arec/sites/cals.arizona.edu/arec/files/publications/contrib_ag_maricopa_county_GRIC_economies.pdf)

Various local foods NGOs and tribal agricultural and nutrition agencies wanted to coordinate efforts to address issues about food access and production, however the baseline data for effective planning was lacking. This paper examined the structure of agricultural production systems in Maricopa County and the Gila River Indian Community to provide information about the potential for expanding production of local foods given increasing water resource constraints. Since publication, authors have received emails from the NGOs and tribal agencies asking for additional interpretations and data sources on local and tribal agricultural production.

Weiss J and MB Roudaut. 2018. An Introduction to Improved Understanding of Climate Variability and Change Relevant to Orchards and Vineyards in Arizona and New Mexico. CLIMAS: Tucson, AZ.

This series of five information sheets presented example topics and historical data analyses of temperature conditions relevant to specific orchard and vineyard sites. These were used as starting points for discussion and future project collaboration. Documents were produced for the Farmington Agricultural Science Center, Los Lunas 3 SSW, New Mexico State University, Bonita, AZ, and Yavapai College in Verde Valley.

## Selected Applications of CLIMAS Work

---

### Projections of Climate Impacts on Vector-Borne Diseases and Valley Fever in Arizona

CLIMAS Researchers: H. Brown and M. Wilder

West Nile virus and Valley fever are two infectious diseases in the Southwest whose causes—two species of mosquito and a fungus—are strongly connected to temperature and precipitation. The

Arizona Department of Health Services collaborated with CLIMAS researchers to demonstrate how regional climate changes will alter the prevalence of these diseases. Findings informed statewide strategies to reduce risk and exposure to these diseases and informed the 2017 Climate and Health Adaptation Plan for the State of Arizona.

<http://www.azdhs.gov/documents/preparedness/epidemiology-disease-control/extreme-weather/pubs/arizona-climate-health-adaptation-plan.pdf>

### **Arizona Business Resilience Initiative – An Initiative to Support Arizona’s Business Community in Managing Climate Risk**

**CLIMAS Investigators:** B. McMahan, M. Crimmins, D. Ferguson, and A. Gerlak

This initiative was focused on addressing climate and environmental risks identified by a local electric utility – Tucson Electric Power (TEP) – as key concerns for operating in the arid Southwest. These risks included heat, wildfire, water, and air quality. Extreme temperatures, drought, and climate variability affect the utility’s planning and decision-making. In addition, TEP must increasingly respond to the environmental, legislative, and economic impacts of regional climate change. A final report from this collaboration synthesizes research findings that help inform TEP’s planning process. TEP representatives provided feedback on the report and aided with synthesizing results. Charts, graphs, and tables from the report appear in TEP documents, plans, and presentations. Information is used to inform general strategies for the utility’s long-term plan. A TEP representative reflected on the project: “We supplied certain business information, and the UA team of experts applied advanced analytical tools and methodologies, such as GIS and climate modeling to our data. They were then able to develop short- and long-term risk profiles, for us to evaluate as part of our long-term planning” (related news coverage: <https://uaatwork.arizona.edu/lqp/ua-collaboration-tep-creates-framework-future-industry-partnerships>.) Final report: <https://www.climas.arizona.edu/publication/report/climate-risks-and-impacts-regional-utility-sector-results-collaborative-research>.

### **Community Climate Profiles**

**CLIMAS Investigators:** A. Meadow, J. Weiss, L. Keith, and S. LeRoy

The City of Flagstaff, AZ consulted CLIMAS researchers to develop a climate profile to help them design scientifically informed climate adaptation strategies. Researchers provided geographically specific climate information, including historical data and future scenarios, to support their local adaptation planning. The city’s profile included several projected scenarios, such as warmer temperatures causing less precipitation to fall as snow during the winter rather than rain. Less snow will directly impact local economies, especially tourism and recreation. City officials used profile data to create targeted adaptation goals for Flagstaff’s first Climate Action and Adaptation Plan. (Related news coverage: [https://azdailysun.com/news/local/report-dozens-of--degree-days-and-less-snow-in/article\\_3a7f529e-7449-53b7-ad37-a4dc7af776fa.html](https://azdailysun.com/news/local/report-dozens-of--degree-days-and-less-snow-in/article_3a7f529e-7449-53b7-ad37-a4dc7af776fa.html).)

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

**CLIMAS Investigators:** G. Frisvold and X. Qiao

George Frisvold developed methods to measure water use efficiency and productivity. He analyzed water efficiency improvements that were adopted in Yuma County, Arizona, one of the top US counties for vegetable production and overall crop production. Growers adjusted their cropping patterns away from longer-season crops with summer acreage and replaced them with shorter-rotation, winter, high-value vegetable crops. Based on Frisvold’s analysis, these

adjustments brought gross returns valued at more than \$4,000 per acre larger. Other groups have since expressed interest in collaborating to improve methods that measure the impact of improved irrigation practices and water use efficiency, including the Barilla Pasta Company and the World Bank's Water Global Practice.

## Contributions to the NIDIS Regional Drought Early Warning System

---

Several CLIMAS projects contributed to developing capabilities and methodologies to advance drought early warning systems in the Southwest US. These projects aim to improve the provision of drought-related data and information across the Inter-Mountain West Drought Early Warning System (IMW DEWS). Project titles are categorized below. Further details about contributions can be found in their correlating project descriptions.

### **Convene and collaborate with regional stakeholders**

- Southwest Tribal Data Summit: Partnering with Southwest Indigenous Communities to Identify Data Challenges, Needs, and Opportunities (p. 5)

### **Improve regional and local capabilities to understand, educate, and communicate drought information and awareness**

- CLIMAS 2016-2017 Assessment – Identifying Emergent Research Priorities and Expanding the Regional Network (p. 16)

### **Deliver products and services at regional and local levels**

- The Southwest Climate Outlook (p. 10)
- Southwest Climate Podcasts (p. 10)
- Southwest Climate Information Hubs (p. 11)

### **Demonstrate drought risk reduction strategies using drought monitoring and prediction information in partnership with users and federal, state, regional, and local agencies.**

- Evaluating Existing and Developing New Drought Indices using Modeled Soil Moisture Time Series (p. 2)
- Exploring the Use of Climate and Remote Sensing Data to Support Drought Monitoring across the Southwest US (p. 16)

### **Evaluate drought risk communication and reduction strategies around the impacts of extreme events and overall resilient development practices**

- A Colorado River Shortage Declaration: Planning, Responses, and Consequence (p. 2)
- Adaptation Strategies for Water and Energy Sectors in the Southwest (p. 15)
- CLIMAS Heat Extremes Assessment (HEAT) – Exploring the Cascading Effects of Climate Extremes in the Southwest (p. 15)
- Adaptation to Climate Variability and Change: Markets, Policy, Technology, and Information (p. 17)
- Sectoral Impacts of Drought and Climate Change (p. 17)

## Data Management Plan

---

Ten new projects started this year on our new award that began in 2017. Since most of these projects are in their initial stages, no data sets have been produced to date. Arrangements are being made to ensure that data will be available to the public when appropriate.

## Continuing CLIMAS Projects

---

### Adaptation & Vulnerability

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

**CLIMAS Investigators:** B. Colby, G. Frisvold, R. Isaacs, and R. Young

**Abstract:** This project examines potential climate adaptation strategies related to water and energy in the Colorado River and Rio Grande basins. Researchers investigated how climate influences market prices of water. They developed water and energy-supply reliability tools and guidelines for using these tools to enhance supply reliability.

**Deliverables:** Implementation and expansion of the Colorado River Basin System Conservation Pilot Program, resulting in many local-scale water resilience arrangements. Five publications regarding water demand, water trading, tribal water rights and management, water conservation, and drought. Seven presentations for stakeholders in tribal agencies, water management, and policy fields. Colby served on eight advisory committees for government agencies and non-governmental organizations.

**Findings:** Stakeholder groups, NGOs and public agencies are collaborating to provide funding and technical expertise in order to facilitate voluntary water sharing agreements between urban, environmental and agricultural interests, which improve regional resilience.

**Additional Support:** NOAA—Regional Climate Centers; NOAA—Sectoral Applications Research Program (SARP); US Bureau of Reclamation; Walton Family Foundation; The Sonoran Institute; NIDIS—Coping with Drought

#### **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, and M. Crimmins

**Abstract:** Climate extremes pose serious threats to human health, place increasing demands on municipal services and infrastructure, and threaten the long-term sustainability of a region. 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.

**Deliverables:** Project analysis and framework has helped inform ongoing CLIMAS vulnerability assessment frameworks by highlighting the intersection of acute impacts with long-term patterns of climate and environmental vulnerability. Results from this project informed the development of two other CLIMAS projects: 1) Developing Integrated Heat Health Information for Long-term Resilience and Early Warning; 2) Evaluating the Use of Urban Heat Island and Heat Increase Modeling in Land Use and Planning Decision-Making

**Additional Support:** NIDIS—Coping with Drought

#### **CLIMAS 2016-2017 Assessment – Identifying Emergent Research Priorities and Expanding the Regional Network**

**CLIMAS Investigators:** B. McMahan, L. Keith, and D. Ferguson

This project aims to better understand the different climate and environmental threats facing urban and rural communities in Arizona and New Mexico. The project focuses on: 1) participating in the lower San Pedro River conservation collaborative to provide expertise about drought and climate vulnerability that is tailored to specific regional challenges; 2) expanding our analysis in the Gila River basin to identify potential collaborators and regional priorities regarding drought and climate; 3) collaborating with Pima County Office of Emergency

Management to update their hazard mitigation plan. This project contributes to the Intermountain West Drought Early Warning System (IMW DEWS).

**Deliverables:** Facilitated quarterly community-based conservation discussions about research and outreach priorities for the lower San Pedro River. Summarized municipal planning related concerns and priorities for 6 communities in AZ and NM. Developed a collaborative relationship with Pima county Office of Emergency Management.

**Additional Support:** Southwest Decision Resources; NIDIS—Coping with Drought; US Department of Interior—Landscape Conservation Cooperatives

## Decision Support

### Exploring the Use of Climate and Remote Sensing Data to Support Drought Monitoring Across the Southwest United States

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

**Abstract:** DroughtView combines geovisualization tools with remote sensing products to detect drought conditions. The DroughtView tool served as a key piece of information to help the National Resources Conservation Service, US Bureau of Land Management, and US Forest Service range managers determine drought conditions and Farm Services Agency drought disaster assistance eligibility. DroughtView is a web-based decision-support tool for computers and mobile devices that combines satellite-derived measures of surface greenness with additional geospatial data so that users can visualize and evaluate vegetation dynamics across space and over time. <https://droughtview.arizona.edu/>

**Deliverables:** One publication for Arizona Cooperative Extension regarding DroughtView. Five presentations (two invited and three poster presentations) regarding DroughtView.

**Additional Support:** NOAA—Sectoral Applications Research Program (SARP); NIDIS—Coping with Drought; The University of Arizona—Water, Environmental, and Energy Solutions; US Department of Agriculture—Regional Climate Hub

### Western Region Climate Services Provider Database

**CLIMAS Investigators:** B. McMahan

**Abstract:** Adapting to climate change requires that decision makers have information that is relevant to solve their problems at hand. Unfortunately, potential users of climate information often do not know where to look for relevant information, nor are producers of climate information well connected to potential users, resulting in a gap that separates the supply and demand of climate information. This project first created a comprehensive database of climate service providers in the western US. Now researchers are conducting a survey of climate service providers to better understand what services are in demand, how providers are developing and maintaining their stakeholder networks, and how they evaluate climate services development and stakeholder engagement. The Western Region Climate Service Providers Database:

<http://wrcc.dri.edu/ClimSvcProviders/>

**Findings:** Emerging survey results show: 1) top-ranked services include capacity building and information dissemination; 2) providers focus on drought, water, and climate/weather; 3) topical gaps include energy, social vulnerability, and human health; 4) services also include how to use available data.

**Additional Support:** NOAA—Western Regional Partnership; NOAA—Regional Climate Services Directors; NOAA—National Weather Service; Western Water Assessment

## Drought

### Sectoral Impacts of Drought and Climate Change

**CLIMAS Investigators:** G. Frisvold, X. Qiao, X. Wu, and C. Hu

**Abstract:** This project examines the impacts of drought and climate change on climate sensitive sectors in the Southwest, focusing on agriculture as well as outdoor recreation and tourism. In response to frequent stakeholder requests, the project investigates how water transfers would affect the local economies or rural, water-exporting communities. The project examines how drought and climate change would affect the 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.

**Findings:** Rough estimates suggest that local foods sales and spending in Maricopa County could total in the tens of millions of dollars annually, based upon national averages.

While \$318 million of Maricopa County's agricultural production was for non-food crops, much of that was production of feed crops for livestock, of which the dairy industry is an important user. Production of feed and alfalfa could be part of the dairy industry value chain. The United Dairymen of Arizona and the Arizona Department of Agriculture have approached CLIMAS researchers to collaborate on a study regarding the sectoral impacts of drought on the Arizona dairy and related industries (e.g. such as feed and forage production).

**Deliverables:** Two publications regarding agricultural production systems and water transfers from agriculture to urban uses. Five presentations regarding agricultural water use. One media story about climate change impacts to Arizona agriculture.

**Additional Support:** US Geological Survey; US Bureau of Reclamation; US National Park Service; Cotton Incorporated; Yuma County Arizona Cooperative Extension; NOAA—Regional Climate Centers; US Department of Agriculture—Climate Hubs; NIDIS—Coping with Drought

## Economics & Livelihoods

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

**CLIMAS Investigators:** G. Frisvold and X. Qiao

**Abstract:** This project examines the role of water management information and irrigation technologies in agricultural adaptation to climate variability and changes in the 17 western-most US states. Issues addressed include: (a) farmer demand for different sources of public and private water management information; (b) adoption of scientific methods and use of electronic media to schedule irrigation; and (c) how climate affects choice of irrigation technologies.

**Findings:** Through extensive changes in irrigation technologies, production practices, and investments in irrigation infrastructure, Yuma agriculture shifted from perennial and summer-centric crop production to winter-centric, multi-crop systems focused on high-value vegetable crops, leading to improvement in irrigation efficiency and overall water conservation. Return flows from the system, which were once characterized as an indicator of inefficiency, provide valuable environmental services to the Colorado River Delta ecosystem. What have been characterized as inefficiencies actually improves the ecosystem. Ecosystem services, in turn, have attendant economic benefits.

**Deliverables:** One publication regarding irrigation efficiency. One presentation about patterns of agricultural crop abandonment. Other groups are interested in developing alternative and improved methods of measuring water use efficiency, including ongoing discussion with the pasta company Barilla, which purchases durum wheat from Arizona farmers. They want to

develop sustainability assessments of their sources of pasta ingredients. The World Bank's Water Global Practice is interested in our methods to measure water use productivity.

**Additional Support:** US Department of Agriculture—National Agricultural Statistics Service; US Department of Agriculture—Economic Research Service; US Bureau of Reclamation; Cotton Incorporated; NIDIS—Coping with Drought

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

**CLIMAS Investigators:** B. McMahan, M. Crimmins, D. Ferguson, and A. Gerlak

**Abstract:** The Arizona Business Resilience Initiative developed a methodology for assessing business opportunities and managing risks to operations associated with climate change and climate variability. This research answers two questions: Based on the current state-of-knowledge in climate change impacts and vulnerability assessment, what are the most probable impacts on the company's operations and projections due to climate change, and 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?

**Deliverables:** This project applied participatory climate services development methodologies in the private sector. The final project report was published outlining the process of working with and the key concerns for electric utilities in the Southwest. Tucson Electric Power is using this information to adapt and inform their Integrated Resource Plan. One peer-reviewed article reviewing climate risk management in the electricity sector. Two presentations about qualitative climate risk assessments for the private sector. Led to new project about small scale solar feasibility on the US-Mexico border.

**Additional Support:** The University of Arizona—Office of Research, Discovery, & Innovation and the Senior Vice President for Research

### **Education & Training**

#### **"Making the Connection between Science and Decision Making" Graduate Seminar**

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

Scientific knowledge can be critical for dealing with complex, socially relevant environmental issues. However, there is a mismatch between the types and format of information available and what is useful for these potential consumers. This seminar, aimed at graduate students from all relevant disciplines, explores concepts at the intersection between environmental science and decision making, including scientific information supply and demand, boundary organizations, co-production of knowledge, and knowledge networks, as well as recognition of the political context for decision making. The seminar is currently being translated to an online professional development version, to be offered in Fall 2018.

**Additional Support:** University of Arizona—School of Geography and Development; University of Arizona—Vice Provost for Digital Learning and Student Engagement; University of Arizona—Office of Digital Learning

### **Environment & Society Fellows Program**

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

The Environment & Society Fellowship was created in 2013 as a funding opportunity for graduate students to practice use-inspired research and science communication. The Fellowship supports projects that connect social or physical science, environment, and decision-making.

Projects must address research and information needs voiced by the students' project partners. Since its inception, the Fellowship program has funded 20 graduate students. In a recent follow up survey, past research fellows indicated that lessons they learned about conducting use-inspired science, engaging stakeholders, communicating science, and collaborating with people outside the University have influenced their current career and research trajectories. Past fellows received approximately \$500,000 in grant awards to extend their work beyond the one-year Fellowship projects. 2017 projects included:

- Women at the Nexus of Agricultural Development and Climate Change Adaptation – A study on Collective Farming in Kerala, India – Sneha Balakrishnan
- Paleoclimatic Indicators of Surface Water Resources in the Chuska Mountains, Navajo Nation – Becky Brice
- Investigating Climate Change, Marginalization and Inequality in the Kaipara Catchment of Aoteraroa New Zealand – Danielle Johnson

In 2018, we designed quarterly training modules for Fellows that focus on different aspects of conducting use-inspired research, including: 1) designing collaborative projects; 2) methods for engaging stakeholders; 3) writing for broad audiences; and 4) designing effective presentations. The five students selected for 2018 are engaged in a number of research activities: assessing historical and current issues regarding water rights in the Owens Valley; understanding how science information is produced, transferred, and used in groundwater governance at the US-Mexico border; estimating survival and abundance of the endangered Sonoran pronghorn; and integrating local and scientific knowledge to address land degradation in Ghana.

<https://www.climas.arizona.edu/education/fellowship-program>

**Additional Support:** University of Arizona—Office of Research, Discovery, & Innovation

## Health

### Developing Integrated Heat Health Information for Long-term Resilience and Early Warning

**CLIMAS Investigators:** G. Garfin, S. Leroy, and B. McMahan

**Abstract:** Extreme heat is a key public health risk in the adjacent cities of El Paso, TX, Ciudad Juárez, Chihuahua, and Las Cruces, NM. Projected temperature changes, combined with the urban heat island effect and regional poverty, expose urban areas with high vulnerabilities to heat-health risks. This project increases preparedness and capacity to adapt to extreme high temperatures and heat waves in Rio Grande/Bravo basin border cities through several approaches: identifying key heat-health parameters and target populations for heat-health early warning; determining a calendar of climate- and weather-related public health decisions; assessing capacity for coordinated heat-health early warning; and facilitating discussions toward developing a community of practice and mutual learning within a network of regional cities. The project advances frameworks for a National Integrated Heat Health Information System and initiatives within the Global Framework for Climate Services.

**Deliverables:** Two publications documenting climate services for heat health in the US-Mexico Border region. A website describing the partnership and available resources (<https://www.borderheat-healthpartnership.org/>). A database of people in the region working on heat and health issues. A workshop bringing together project partners, stakeholders, and researchers. Five presentations about health risks and extreme heat in the US-Mexico border region. Two media interviews (radio and online news) about extreme heat impacts.

**Additional Support:** NOAA—National Weather Service; NOAA—Regional Climate Services Directors; Texas Tech University; University of Texas at El Paso; University of Arizona—Agnes Nelms Haury Program in Environment and Social Justice; NASA DEVELOP Grant

### **Air Quality and Climate**

**CLIMAS Investigators:** D. DuBois, A. Arredondo, Z. Ghodsizadeh, J. Fuentes, J. Gutierrez, O. Nayaes, S. Engle, M. Bean, M. DeAntonio, and M. Klose

**Abstract:** Dust storms in the Southwest United States and northern Mexico continue to create serious health and safety issues. In a continued effort to locate the sources of dust, researchers continued surveillance of dust storms and determined the latitude and longitude of these storms.

**Findings:** Researchers completed their work designing a method to characterize dust storm events using data from the North American Regional Reanalysis model archive. Based on 60 dust storm events, they generated patterns to compare with non-dust days. While that method proved to be successful in identifying dust storms, it also identified other non-dust events. One particular variable that needs to be included in the future is soil moisture.

**Deliverables:** Five presentations showing results of providing early warning for dust storms to stakeholders. Social media videos depicting time lapses of dust storms. Research has been promoted on social media by local TV and newspapers in Las Cruces, NM and El Paso, TX. Researchers use Twitter regularly to push early warnings for dust storms. The account has more than 1,200 followers and some tweets are retweeted by the media.

**Additional Support:** NOAA—National Weather Service; NIDIS—Coping with Drought

### **Climate and Health Adaptation Monitoring Program (CHAMP): Identifying gaps in stakeholder needs regarding the climate-health connection**

**CLIMAS Investigators:** H. Brown, D. Ferguson, and E. Barrett

As part of the Climate-Ready States and Cities Initiative, the Center for Disease Control (CDC) engaged 16 states and two large cities to implement a five-step program called Building Resilience Against Climate Effects (BRACE) in 2009. The program aimed to help communities prepare for the health effects of climate change. As that project ends, the CDC is now supporting the monitoring and evaluation of the efforts developed under BRACE in a new effort called the Climate and Health Adaptation Monitoring Program (CHAMP). To support these monitoring and evaluation efforts, investigators are working to map the Arizona network of climate/health advocates, to identify gaps stakeholders need regarding the climate-health connection, and to develop strategies to better support these efforts.

**Deliverables:** A report prepared for the US Centers for Disease Control and Prevention Climate-Ready States and Cities Initiative that compiles health adaptation ideas, direction, and activities to help guide Arizona stakeholders in building resilience against the effects of climate hazards.

**Additional Support:** Arizona Department of Health Services

## APPENDIX: 2017-2018 Publications

---

- Clarke A, B Colby, and G Thompson. 2017. Household Water Demand Seasonal Elasticities: A Stone-Geary Model under an Increasing Block Rate Structure. *Land Economics* 93(4):608–630.
- Colby B and R Young. 2018. Tribal Innovations in Western Water Management. *Western Economics Forum* 16(1):38-46.
- Colorado River Research Group. 2018. When is Drought Not a Drought? Drought, Aridification, and the "New Normal." A Publication of the Colorado River Research Group, "An Independent, Scientific Voice For The Future Of The Colorado River."  
[https://www.coloradoriverresearchgroup.org/uploads/4/2/3/6/42362959/crrg\\_aridity\\_report.pdf](https://www.coloradoriverresearchgroup.org/uploads/4/2/3/6/42362959/crrg_aridity_report.pdf)
- Colorado River Research Group. 2017. Innovations in Agricultural Water Conservation and Use: Fertile Ground for Lasting Solutions. A publication of the Colorado River Research Group, "An Independent, Scientific Voice For The Future Of The Colorado River."  
[https://www.coloradoriverresearchgroup.org/uploads/4/2/3/6/42362959/crrg\\_innovations\\_in\\_agriculture\\_june\\_2017.pdf](https://www.coloradoriverresearchgroup.org/uploads/4/2/3/6/42362959/crrg_innovations_in_agriculture_june_2017.pdf)
- Crimmins MA. 2018. Monitoring Precipitation on Rangelands: Tools, Strategies, and Best Practices. *Proceedings from the 40th Annual Arizona/Utah Range Livestock Workshop and Tour*. Orderville, UT. April 3, 2018.
- Crimmins TM, MA Crimmins, KL Gerst, AH Rosemartin, and JF Weltzin. 2017. USA National Phenology Network's volunteer-contributed observations yield predictive models of phenological transitions. *PLOS ONE* 12(8):e0182919.  
<https://doi:10.1371/journal.pone.0182919>
- Crimmins MA, M McClaran, J Brugger, D Tolleson, and A Hall. 2017. Do-it-yourself construction guide: Rugged accumulation precipitation gauge for remote monitoring. *University of Arizona Cooperative Extension Publication AZ1747*.
- Crimmins MA, M McClaran, J Brugger, D Tolleson, and A Hall. 2017. Rain Gauges for Range Management: Precipitation monitoring best practices guide. *University of Arizona Cooperative Extension Publication AZ1751*.
- Deol S and BG Colby. 2018. Economies of Tribal Nations: Water Rights, Agriculture and Gaming, *Journal of Contemporary Water Research and Education* 163(1):45-63.  
<https://doi.org/10.1111/j.1936-704X.2018.03269.x>
- Duval D, AK Bickel, G Frisvold, X Wu, and C Hu. 2018. Contribution of Agriculture to the Maricopa County and Gila River Indian Community Economies. *Department of Agricultural & Resource Economics, Cooperative Extension Report*. University of Arizona, Tucson, AZ.  
[https://cals.arizona.edu/arec/sites/cals.arizona.edu.arec/files/publications/contrib\\_ag\\_maricopa\\_county\\_GRIC\\_economies.pdf](https://cals.arizona.edu/arec/sites/cals.arizona.edu.arec/files/publications/contrib_ag_maricopa_county_GRIC_economies.pdf)
- Elias E, TS Schrader, JT Abatzoglou, D James, MC Crimmins, JL Weiss, and A Rango. 2017. County-level climate change information to support decision-making on working lands. *Climatic Change* 148(3):355-369. <https://doi.org/10.1007/s10584-017-2040-y>
- El-Vilaly MAS, K Didan, SE Marsh, MA Crimmins, and AB Muñoz. 2018. Characterizing Drought Effects on Vegetation Productivity in the Four Corners Region of the US Southwest. *Sustainability* 10(5):1643. <https://doi.org/10.3390/su10051643>
- El-Vilaly MAS, K Didan, SE Marsh, WJD van Leeuwen, MA Crimmins, and AB Muñoz. 2017. Vegetation productivity responses to drought on tribal lands in the four corners region of the

- Southwest USA. *Frontiers of Earth Science* 12(1):1–15. <https://doi:10.1007/s11707-017-0646-z>
- Frisvold G, C Sanchez, N Gollehon, SB Megdal, and P Brown. 2018. Evaluating Gravity-Flow Irrigation with Lessons from Yuma, Arizona, USA. *Sustainability* 10(5):1548. <https://doi:10.3390/su10051548>
- Garfin G and S LeRoy. 2017. NIHHS Rio Grande-Rio Bravo 2017 Summer Meeting: Evaluation, Knowledge Sharing, and Next Steps Summary. CLIMAS: Tucson, AZ. <https://www.climas.arizona.edu/publication/report/nihhis-rio-grande-rio-bravo-2017-summer-meeting-evaluation-knowledge-sharing-and>
- Garfin G, S LeRoy, and H Jones. 2017. Developing Integrated Heat-Health Information for Long-term Resilience and Early Warning for the El Paso-Juárez-Las Cruces Region. Final Report. CLIMAS: Tucson, AZ.
- Garfin G, S LeRoy, M Muth, H Jones, M Ibarra Ochoa, JL Vazquez Aguirre, M Shafer, D Brown, J Saldana Colin, G Velazquez Angulo, ML Romo Aguilar. 2017. Climate Services for Coping with Climate Change, Drought, and Extreme Heat in the México-US Border Region. In MJ Montero Martinez and OF Ibanez Hernandez (eds). *Cuenca del Río Conchos: Una Mirada desde las Ciencias ante el Cambio Climático*. Jiutepec, Morelos, Mexico: Instituto Mexican de Tecnología del Agua, pp. 23-57.
- Gerlak AK and B McMahan. 2017. Climate risks and impacts for the regional utility sector: results of a collaborative research process with Tucson Electric Power. CLIMAS: Tucson, AZ. <https://www.climas.arizona.edu/publication/report/climate-risks-and-impacts-regional-utility-sector-results-collaborative-research>
- Gerlak AK, J Weston, B McMahan, RL Murray, M Mills-Novoa. 2017. Climate risk management and the electricity sector. *Climate Risk Management* 19:12-22. <https://doi.org/10.1016/j.crm.2017.12.003>
- Kendy E, B Aylward, L Ziemer, B Richter, B Colby, T Grantham, L Sanchez, W Dicharry, E Powell, S Martin, P Culp, L Szeptycki, and C Kappel. 2018. Water Transactions for Streamflow Restoration, Water Supply Reliability, and Rural Economic Vitality in the Western United States. *Journal of the American Water Resources Association* 54(2):487-504.
- McAfee SA, GT Pederson, CA Woodhouse, and GJ McCabe. 2017. Application of synthetic scenarios to address water resource concerns: A management-guided case study from the Upper Colorado River Basin. *Climate Services* 8, 26-35. <https://doi.org/10.1016/j.cliser.2017.10.003>
- McCabe GJ, D Wolock, GT Pederson, CA Woodhouse, and SA McAfee. 2017. Evidence that recent warming is reducing upper Colorado River Flows. *Earth Interactions* 21:1-14. <https://doi:10.1175/EI-D-17-0007.1>
- Meadow A, S LeRoy, J Weiss, and L Keith. 2018. Climate Profile for the City of Flagstaff, Arizona. CLIMAS: Tucson, AZ.
- Meko DM, CA Woodhouse, and ER Bigio. 2017. University of Arizona Southern California Tree-Ring Study. Final Report to California Department of Water Resources, Agreement 4600011071. <https://www.water.ca.gov/-/media/DWR-Website/Web-Pages/Water-Basics/Drought/Files/Publications-And-Reports/UofAZ-SoCal-tree-ring-report-dec-2017.pdf>
- Qiao X. 2018. Water Use and Climate Effects on Farm Profitability in the Colorado Basin. MS Thesis, Department of Agricultural and Resource Economics, University of Arizona. G. Frisvold major advisor.

- Roach M, E Barrett, H Brown, B Dufour, DM Hondula, H Putnam, and B Sosa. 2017. *Arizona's Climate and Health Adaptation Plan*. A report prepared for the United States Centers for Disease Control and Prevention Climate-Ready States and Cities Initiative. <https://www.azdhs.gov/documents/preparedness/epidemiology-disease-control/extreme-weather/pubs/arizona-climate-health-adaptation-plan.pdf>
- Sall I, G Frisvold, and R Tronstad. 2017. Spatial and Temporal Patterns in Cotton Acreage Abandonment Case Study of Selected Counties in the US Cotton Belt. Selected paper at the 2017 Western Agricultural Economics Association Annual Meetings. Lake Tahoe, Nevada. July 9-11, 2017.
- Weiss J and MB Roudaut. 2018. An Introduction to Improved Understanding of Climate Variability and Change Relevant to Orchards and Vineyards in Arizona and New Mexico for the Farmington Agricultural Science Center, New Mexico. CLIMAS: Tucson, AZ.
- Weiss J and MB Roudaut. 2018. An Introduction to Improved Understanding of Climate Variability and Change Relevant to Orchards and Vineyards in Arizona and New Mexico for Los Lunas 3 SSW, New Mexico. CLIMAS: Tucson, AZ.
- Weiss J and MB Roudaut. 2018. An Introduction to Improved Understanding of Climate Variability and Change Relevant to Orchards and Vineyards in Arizona and New Mexico for New Mexico State University. CLIMAS: Tucson, AZ.
- Weiss J and MB Roudaut. 2018. An Introduction to Improved Understanding of Climate Variability and Change Relevant to Orchards and Vineyards in Arizona and New Mexico for Bonita, Arizona. CLIMAS: Tucson, AZ.
- Weiss J and MB Roudaut. 2018. An Introduction to Improved Understanding of Climate Variability and Change Relevant to Orchards and Vineyards in Arizona and New Mexico for Yavapai College Verde Valley Campus, Arizona. CLIMAS: Tucson, AZ.
- Woodhouse CA and GT Pederson. 2018. Investigating runoff efficiency in upper Colorado River streamflow over past centuries. *Water Resources Research* 54(1):286-300. <https://doi.org/10.1002/2017WR021663>
- Woodhouse CA, DM Meko, ER Bigio, and SE Frederick. 2017. Using Tree-Ring Records for Understanding Droughts in a Long-Term Context: A Guidebook for the California Department of Water Resources. <https://www.water.ca.gov/-/media/DWR-Website/Web-Pages/Water-Basics/Drought/Files/Publications-And-Reports/UofAZ-tree-ring-Guidebook-dec-2017.pdf>
- Vano JA, D Behar, P Mote, DB Ferguson, and R Pandya. 2017. Partnerships Drive Science to Action Across the AGU Community. *Eos* 98. <https://doi.org/10.1029/2017EO088041>
- Weiss J and MA Crimmins. 2017. DroughtView: Satellite-based drought monitoring and assessment. *The University of Arizona Cooperative Extension Publication AZ1737*. [https://cals.arizona.edu/research/climategem/resources/Weiss&Crimmins\(2017\)UACEDroughtView.pdf](https://cals.arizona.edu/research/climategem/resources/Weiss&Crimmins(2017)UACEDroughtView.pdf)