

# The Climate Assessment for the Southwest

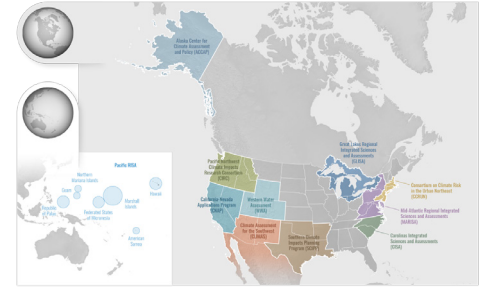
## Annual Report 2018 – 2019





# What is CLIMAS?

The Climate Assessment for the Southwest (CLIMAS) is a NOAA-funded program that connects researchers at the University of Arizona and New Mexico State University to partners from the private sector, academia, and local, state, federal, and tribal governments. Since 1998, CLIMAS researchers have brought the best available knowledge to weather and climate-related challenges in the Southwest. CLIMAS is funded by the Regional Integrated Sciences and Assessments (RISA) program and the National Integrated Drought Information System (NIDIS), both of which are designed to improve the use of climate information in decision making.



## 2018 — 2019 CLIMAS Research Team

### Principal Investigators

Daniel Ferguson (Program Director, Lead PI), Heidi Brown, Michael Crimmins, George Frisvold, Connie Woodhouse

### Co-Principal Investigators

Bonnie Colby, David DuBois, Ladd Keith, Ben McMahan, Alison Meadow, Gigi Owen, Stephanie Rainie, Jeremy Weiss

### Senior Personnel

Christina Greene\*, Sarah Leroy, Mitch McClaran, Craig Rasmussen, Marcel Schaap, Margaret Wilder

### Student Researchers

Antonio Arredondo, Leah Bishop, Patrick Bunn, Hsin-I Chang, Ramon Driesen, Sarah Frederick, Jaylen Fuentes, Zahra Ghodsizadeh, Josue Gutierrez, Chengyang Hu, Rowan Isaacs, Emily Joiner, Valerie Madera-Garcia, Gabe McGowan, Trevor McKellar, Octavio Nayares, Isaac Palomo, Leslie Pilli, Genesis Rodriguez, Marie-Blanche Roudaut, Tess Wagner, Xiaoting Wu, Xinye Wu, Ryan Young

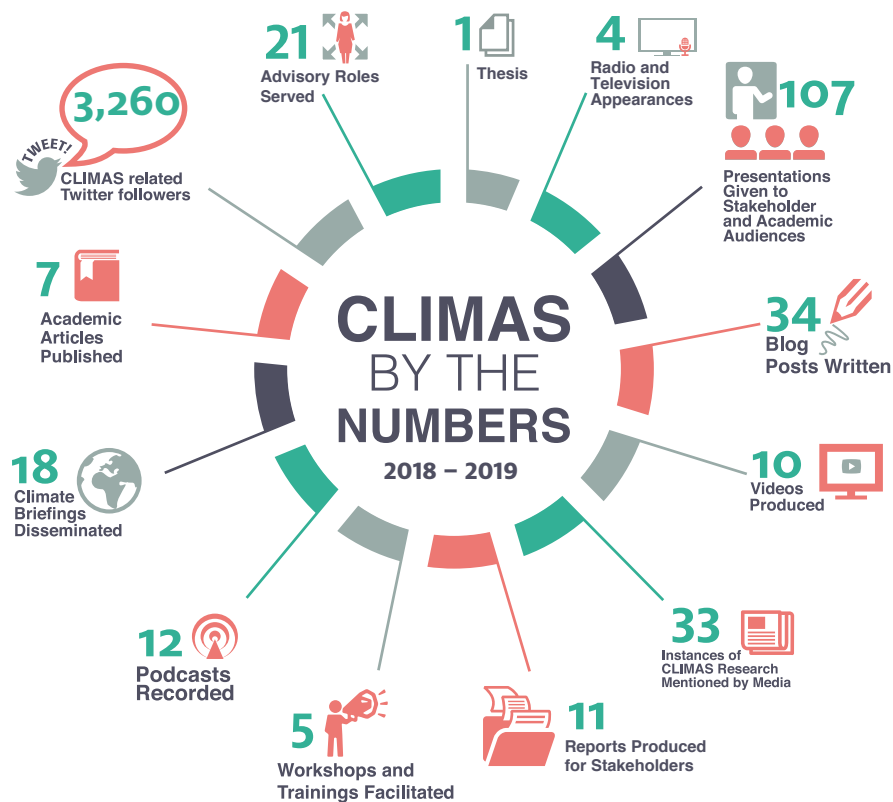
### Research Affiliates

Erika Barrett, Merrill Bean, Michael De Antonio, Stan Engle, Andrea Gerlak, Zack Guido, Martina Klose Environment & Society

### Fellows

2018 — Tamee Albrecht, Sophia Borgias, Stephanie Doerries, Marie-Blanche Roudaut;  
2019 — Alma Anides Morales\*, Nupur Joshi\*, Sean Schrag-Toso\*, Norma Villagomez-Márquez\*

\* New additions to the CLIMAS team during the reporting period.





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## New Areas of Focus and Partnerships

### **Is adaptation mal-adaptation? An assessment of mosquitoes and water harvesting**

Green infrastructure, such as rainwater harvesting, is heralded as a way to build sustainable communities and resilience against climate change impacts. Well-maintained green infrastructure design strategies likely have the greatest impact on conservation while limiting the negative consequences of mosquitoes. When infrastructure falls into disrepair or is designed improperly, it may inadvertently become sources of mosquitoes. If green infrastructure is to be used as an adaptation technique, it is important to understand how and when it works best. In the first year of sampling, Heidi Brown and Ladd Keith found mosquito larvae in a basin that held water for up to 7 days instead of draining within 48 hours. In the coming year researchers will investigate why this potentially mal-adaptive green infrastructure was not functioning properly by repeating the sampling and expanding the project.

### **Contributions to the State of the Science report for the Colorado River Basin**

Connie Woodhouse is working with Western Water Assessment and others on a State of the Science report for the Colorado River Basin. The report was requested by several water management agencies including Southern Nevada Water Authority, Denver Water, and Bureau of Reclamation. A draft report will be completed in summer 2019. Woodhouse is also beginning work with colleagues on content for the U.S. Bureau of Reclamation's Baseline Assessments and SECURE Water Act Report 2021. The report's lead author is focusing on paleohydrology to evaluate water supply and risks as outlined in the SECURE Water Act (PL-111-11 section 9503(c)) for the 2021 report, in hopes of sidestepping issues related to climate change and global climate models.

### **Collaborating with an electric utility to reduce greenhouse gas emissions**

Based on the results of a previous CLIMAS project, Tucson Electric Power contracted CLIMAS researchers Ben McMahan and Andrea Gerlak to explore plausible scenarios for greenhouse gas and carbon reduction in their energy portfolio. These scenarios will focus on internal data regarding the economics of these portfolio decisions and external impacts (e.g., social, environmental, climate) that could affect these decisions. This project will inform the company's integrated resource plan in 2020.





PHOTO CREDIT: JEREMY WEISS

### **Assessing drought and climate vulnerability and resilience in New Mexico's Rio Grande basin**

The 2018 New Mexico Drought Plan calls for more in-depth assessments of state drought vulnerabilities. Led by Christina Greene, this project aims to identify stakeholder concerns and drought research priorities along the Rio Grande Basin using a drought and climate vulnerability assessment. Initial areas of concern identified by the New Mexico Drought Task Force include water, economy, fire, recreation, health, agriculture, and the environment. This project will produce a set of emergent drought research priorities to guide subsequent years of CLIMAS and NIDIS project work.

### **Sectoral impacts of drought and climate change**

This project examines the impacts of drought and climate change on climate sensitive sectors in the Southwest, focusing on agriculture and outdoor recreation. This year, George Frisvold met with stakeholder groups to collaboratively develop three grant proposals for the upcoming year:

- » An analysis of the economic impacts to the Graham and Greenlee County economies from reduced agricultural production in the event of hypothetical reduced water supply scenarios based upon situations modeled in Scenarios for Upper Gila River Watershed from the University of Arizona Water Resources Research Center.
- » An analysis of methods to value agricultural water and develop voluntary acquisition programs.
- » Economic impacts of drought on agriculture, recreational tourism, and rural communities

### **Collaborative research on environmental risks and built environment in the Southwest borderlands**

This scoping project explores opportunities for collaboration in the Arizona-Sonora portion of the U.S.-Mexico border region that emphasize environmental risks and air quality, small scale computing and technology, and citizen science monitoring of environmental phenomena. In fall 2018, Ben McMahan helped convene an environmental workshop to identify emergent areas of interest. This workshop led to a focus on solar heaters and their relevance to climate and air quality in the Nogales region. Another workshop is scheduled for the fall of 2019.



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PHOTO CREDIT: JEREMY WEISS

### **“Make Our Planet Great Again”**

Based on his CLIMAS project—Improved Understanding of Climate Variability and Change Relevant to Orchards and Vineyards in Arizona and New Mexico—investigator Jeremy Weiss was one of 68 recently awarded laureates for the Short-Stay Program of the “Make Our Planet Great Again” initiative launched by France’s President Emmanuel Macron. Within the framework of the initiative, France’s ministries of Europe and foreign affairs and of higher education, research, and innovation have implemented this program for foreign scientists seeking to do research on a topic related to earth systems, climate change and sustainability, or energy transition. Weiss will be in Avignon for two weeks in November to collaborate with staff from the AgroClim service unit of the Environment and Agronomy department within the French National Institute for Agricultural Research, a highly ranked agricultural research institute and center for agricultural sciences. He and his colleagues will develop a process-based approach to identify linkages between tardive frost in orchards and vineyards.

### **The lower San Pedro Conservation Collaborative: stakeholder engagement on climate and environmental vulnerability**

This project focuses on drought and climate related vulnerability in the lower San Pedro and upper Gila watersheds. It is based on collaborative research between Ben McMahan and a mix of stakeholders who have a shared interest in better understanding of climate risks, and the role that drought and climate vulnerability might play in shaping future climate risks. This project asks, what would a local-to-regional perspective on drought/climate vulnerability look like? How might that inform a drought early warning system? The project connects to rural questions about drought and climate vulnerability at the regional scale. These case studies illustrate the complexity of drought early warning systems, reveal the role of drought vulnerability, and connect to locally salient decisions and planning.



# Selected Climate Services and Outputs

## *Regional*

- » Wine grape growers in New Mexico and Arizona are using information provided by the new data periodical, the Climate Viticulture Newsletter, to inform their agricultural planning and operations.
- » Three cities (Avondale and Buckeye, AZ and Santa Fe, NM) and one county (Dona Ana, NM) requested urban heat island maps to inform the conservation of natural and agricultural lands, to prioritize shade interventions along trails and streets, and to reduce size requirements for parking lots.
- » An updated version of the Standardized Precipitation Index Explorer Tool was published to include new features, such as the calculation of the Standardized Precipitation-Evapotranspiration Index (SPEI). This tool is being used in training workshops across the Southwest.

## *New Mexico*

- » The New Mexico Environment Department used CLIMAS support to conduct a workshop in Las Cruces, NM regarding dust. CLIMAS Investigator David DuBois helped arrange speakers, create the agenda, and lead the meeting.
- » David DuBois provided weather information to the El Paso and Albuquerque National Weather Service offices during dust events, based on updates from the dust sensor network on the Lordsburg Playa and photos of real-time dust storms. The Albuquerque (KOB and KRQE) and El Paso (KVIA) TV weather stations often re-tweet these photos and information to their followers. Though social media messaging with the TV stations and the NWS offices in Albuquerque and El Paso, this Twitter audience reaches more than 31,000, who receive information on dust storms, transportation hazards, and research findings.

## *Arizona*

- » The City of Flagstaff directly integrated information from a CLIMAS report into their Climate Adaptation Action Plan. The report presents tailored climate information for the city, including historical records, current trends, and projected changes in average and extreme temperatures and precipitation.
- » The Office of Emergency Management in Oro Valley, AZ used a CLIMAS report summarizing climate and weather-related hazards and cost analyses of past weather events to support a grant application to enhance their emergency preparedness.
- » The Dove Mountain Community in Marana, AZ is using a tailored climate report to inform upcoming architecture and landscape planning projects.
- » The Arizona Department of Health Services is using a report prepared for the U.S. Centers for Disease Control (co-authored by CLIMAS investigator Heidi Brown) regarding successful practices in Pinal, Yuma, and Maricopa counties to update the state's Climate and Health Adaptation Plan.
- » Droughtview, a web-based decision support tool, is being used by farmers, ranchers and resource managers, primarily the U.S. Department of Agriculture—Natural Resource Conservation Service, U.S. Bureau of Land Management and U.S. Forest Service, to inform range management decisions.
- » A study produced by CLIMAS investigator George Frisvold regarding the economic contributions of agriculture in Pinal County, AZ was used to inform negotiations over the Arizona Drought Contingency Plan. The plan was approved by state legislature with a \$9 million budget for groundwater infrastructure projects to mitigate the effects of surface water shortages.
- » A CLIMAS report compared daily minimum temperatures measured at two different locations within a stakeholder orchard in the context of freezing temperatures during late spring. This report assisted orchard managers with accessing and understanding data they were collecting.



# Team Highlight

## Transdisciplinary Environmental Science for Society (TESS) Program

TESS is a newly developed continuing education program at the University of Arizona that draws heavily from the expertise and experiences of CLIMAS researchers. It aims to train future generations of researchers, practitioners, political leaders, and educators to actively confront society's most complex environmental challenges. Available to both academic and non-academic audiences, TESS is a three-part online program about transdisciplinary environmental research and the intersections between science and environmental decision making. The program stems directly from the Connecting Environmental Science and Decision-Making graduate seminar which has been taught by Connie Woodhouse and Daniel Ferguson since 2013. It provides an additional avenue to spread the theory and practice of use-inspired science and transdisciplinary research in general, and about lessons learned from the CLIMAS and RISA programs in particular. TESS has been in development for more than three years. The first course begins in July 2019. Additional support is provided by the University of Arizona—Vice Provost for Digital Learning and Student Engagement and the University of Arizona—Office of Digital Learning. <https://ce.arizona.edu/tess>

# Outreach Highlights

## Selected Workshops and Conferences

### Supporting Tribal Data Governance for Community Resilience: A Southwest Indigenous Climate Summit. University of Arizona, Tucson, AZ. September 11–13, 2018

This event, led by Stephanie Rainie and Daniel Ferguson, fostered discussion about unique issues surrounding Indigenous data sovereignty, tribal data governance, and Indigenous knowledge related to climate resilience efforts within Southwest Indigenous communities. Thirty-five people in attendance. Response to the workshop was positive:

- » “I really valued the opportunities to learn firsthand what others were doing within their communities to overcome barriers and challenges and to strengthen sovereignty and community health. These were the most inspiring and helpful interactions of the event.”
- » “I believe it is important that traditional knowledge can be managed and used for scientific support. The political overtone of the United States capital beltway must be included with any discussion about data management so that it does not take control of the effort, the intent, and the outcome.”

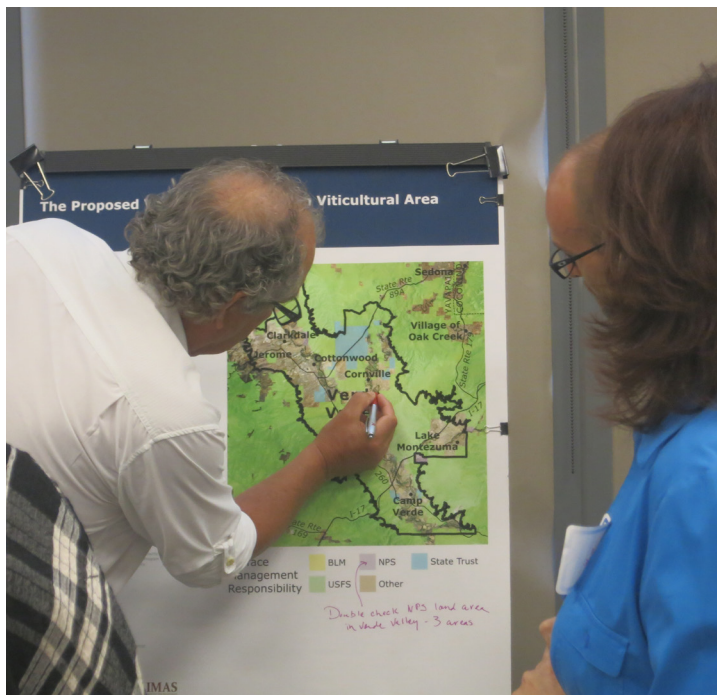


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### An Exchange on Climate and Viticulture in Yavapai County. Yavapai College Verde Valley Campus, Clarkdale AZ, June 6, 2018

Co-organized by Jeremy Weiss and Marie-Blanche Roudaut, presentations and discussions on climate and viticulture in Arizona, the agricultural heritage of Yavapai County, and a new grower-scientist collaborative project about how variations and changes in climate are impacting AZ vineyards. Twenty people in attendance including winegrape growers and viticulture program staff at Yavapai College.

### Pima County Multi-Jurisdictional Hazard Mitigation Stakeholder Workshop. Tucson, AZ. October 11, 2018

The workshop was designed to discuss CLIMAS capacity with workshop attendees to connect some of existing projects to potential hazard mitigation activities. Fifty attendees from city and county government, including police, fire, water, flood control, other emergency managers. Break-out sessions led to discussions on priorities, and information and research needs.



**Climate and Cows Workshop: Building a Climate Toolbox for Range Management. Co-convended with U.S. Department of Agriculture—Natural Resource Conservation Service. Tucson, AZ, June 2019**

Attended by 25 NRCS personnel from across Arizona to learn about tools and strategies to access and use climate data for land management.

**Southern New Mexico Fugitive Dust Symposium and Workshop. Las Cruces, NM, April 17, 2019**

Attended by 40 people and 20 additional people online. Audience was a mix of state agency personnel (e.g., NM Department of Transportation, NM Department of Health), Las Cruces City personnel, and citizens interested in dust issues. The workshop was a collaboration between CLIMAS and the NM Environment Department, Air Quality Bureau. The workshop was held to give updates about the human health impact of dust and to promote discussion about new fugitive dust regulations in Luna and Dona Ana Counties.

## Outreach to the U.S. Senate

Daniel Ferguson worked with the RISA executive committee to convene a RISA-focused briefing for U.S. Senate staff in December 2018. Several staffers attended, as well as leadership representatives from NOAA—Office of Atmospheric Research and the NOAA—Climate Program Office. Ferguson and Lisa Dilling (Western Water Assessment) also met with staff from the U.S. Senate Committee on Commerce, Science and Transportation. Those staffers contacted Ferguson and Dilling in spring 2019 to identify scientists to testify at a committee hearing on climate change. Radley Horton (Consortium for Climate Risk in the Urban Northeast) testified.

## Colloquia and Presentations

### CLIMAS Colloquium Series

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 often archived on the CLIMAS 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. This year speaker topics included water harvesting as a maladaptation, the use of urban heat modeling in land use planning, and the development of a visualization tool for the North American monsoon.

### New Mexico State University Climate Change Speaker Series

This series serves as a way to engage the University and the greater Las Cruces community in discussions about climate change. Six speakers spoke in 2018 and four in 2019. Between 100—250 attendees came to each session. After each talk, a moderated discussion between the audience and the speaker was held.

### CLIMAS-Related Presentations

Overall, members of the CLIMAS team gave 107 presentations about their research this year. Audiences included the general public, project stakeholders, trade associations, government officials, leaders of Native Nations, and other academics.



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PHOTO CREDIT: MIKE CRIMMINS



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## Knowledge Co-Production Activities

### **Science to Support Decision Making: The Influence of Climate on Lower Colorado Streamflow Variability Project Kickoff: University of Arizona, Tucson, AZ, October 2, 2018**

This workshop was the kick-off meeting for Connie Woodhouse's research project in the Lower Colorado River basin. Twelve water resource managers attended, who gave guidance on research design, including: basins of interest, types of analyses, and ideas for other approaches to climate/flow analysis. Project Follow-up: Virtual meeting, April 2, 2019. Seven water resource practitioners attended. Researchers showed results from a climate/water flow analysis for one river basin. Project Website: Anticipating Future Impacts on Streamflow using Multi-Century Climate Records and Applied Hydrologic Models. Contains information about and access to the products generated from this project.

<https://cwoodhouse.faculty.arizona.edu/content/colorado-river-research-southwest-climate-adaptation-science-center-project>

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

Ladd Keith and Tess Wagner held several meetings with city and county governments to develop urban heat island maps, including: the City of Buckeye, AZ; the City of Santa Fe, NM; the City of Avondale, AZ; and Dona Ana County, NM. These partner cities and county have indicated they want to use the maps to help inform the conservation of natural and agricultural lands, prioritize shade interventions along trails and street corridors, and reduce the amount of parking lots required.

### **Developing a drought monitoring playbook for Arizona rangelands. March 7, 2019, Tucson, AZ**

Seven U.S. Department of Agriculture—Natural Resource Conservation Service personnel provided feedback on Trevor McKellar's preliminary research results and provide guidance on project development. Discussions led to refinements in research approach and how results will be communicated in future presentations and the development of a web application.





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## Virtual Outreach Activities

### **New Mexico Climate Twitter Account**

David DuBois continued his use of Twitter via the NM Climate Center account (@nmclimate). This account has 1660 followers as of May 2019, which increased by 395 over the past 12 months. Average monthly impressions range from 31K—65K. The posts with the highest amount of interest depict monthly climate summaries and amounts of snowpack. One specific use of Twitter was to promote awareness of dust storm hazards on highways. Through this account DuBois provided weather information to the El Paso and Albuquerque National Weather Service offices during dust events, based on updates from the dust sensor network on the Lordsburg Playa and photos of real-time dust storms. Sometimes, the Albuquerque (KOB and KRQE) and El Paso (KVIA) TV weather stations re-tweeted these photos and information to their followers. Though social media messaging with the TV stations and the NWS offices in Albuquerque and El Paso, this Twitter audience reaches more than 31,000, who receive information on dust storms, transportation hazards, and research findings.

### **CLIMAS Twitter Account**

The CLIMAS program's Twitter account (@CLIMAS\_UA) has more than 1,600 followers as of May 2019. Posts that generate the highest amount of interest this year were related to the Southwest Climate Podcast, winter precipitation and snowpack, the 2018 summer monsoon, and reservoir diagrams in the Southwest Climate Outlook.

### **The Southwest Climate Outlook (SWCO).**

SWCO summarizes climate and weather information from disparate sources in nonscientific language, providing more than 1,600 people with monthly climate-related information. Since SWCO's inception in 2002, stemming from the END InSight project, the publication has evolved into a tool for two-way communication with stakeholders and a platform for responding to needs throughout the region. Twelve issues were distributed between June 2018 through May 2019. [www.climas.arizona.edu/swco](http://www.climas.arizona.edu/swco)

### **The Rio Grande—Bravo Outlook (RGBO)**

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, 6 issues were published. <http://www.climas.arizona.edu/rgbo>





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### **The Southwest Climate Podcast**

CLIMAS scientists discuss climate-related issues in monthly climate podcasts. The podcasts synthesize information from disparate sources that often do not have a Southwest bent, translating the national and global discussions into what it means for the Southwest. The podcasts also add insight to the discussions by bringing in latest climate science, covering climate-related topics with nuance but not shrouded in technical jargon. Twelve episodes aired between June 2018 through May 2019. New thematic ideas for the podcast are in development for 2019–2020.

[www.climas.arizona.edu/media/podcasts](http://www.climas.arizona.edu/media/podcasts)

### **Southwest Climate Information Hubs**

These hubs are a repository for information about climate topics of particular importance to the southwestern region of the U.S. Based on Google analytics, these pages tend to garner the most traffic on the CLIMAS website. Viewers are most interested in temperature and precipitation dynamics, the monsoon, and information about the El Niño Southern Oscillation.

### **Media Outreach Activities**

RISA Program Video on CLIMAS Dust Research. NOAA—RISA’s CLIMAS Team: Science Clears the Air in Dust Storm Response. The NOAA—Climate Program Office highlighted David DuBois’ research on wind, dust, and health impacts in this video. Interstate 10 traverses southwest New Mexico connecting Las Cruces with El Paso, TX and Tucson, AZ. Dust storms in the Southwest can create dangerous and fatal driving conditions, reducing visibility to near zero with very little warning. Interstate 10 is especially vulnerable to dangerous dust-related driving conditions as it passes through a dry lake bed west of Lordsburg, near the Arizona border. CLIMAS researchers built on existing partnerships with state transportation managers from New Mexico and Arizona to address the impacts of extreme drought and dust storms on transportation systems. The team characterized and documented the climatic and visual conditions that exist during these storms through interviews, time-lapse camera imagery, and dashboard cameras and worked closely with the New Mexico Department of Transportation, NWS Weather Forecast Offices, and trucking companies to improve education and warning about dangerous dust storm events.

<https://youtu.be/ENyIO-coRKg>





PHOTO CREDIT: DAN FERGUSON

## Media Coverage of CLIMAS Research

CLIMAS researchers receive numerous requests for interviews and media appearances about their research. This year, CLIMAS researchers were quoted or referenced in 33 online news articles, spoke as guests on two radio shows or podcasts, and appeared in two television interviews. Notable examples include:

Drought plan fight between Arizona farms and cities escalates. Arizona Daily Star, January 19, 2019. (G. Frisvold)

[https://tucson.com/news/local/drought-plan-fight-between-arizona-farms-and-cities-escalates/article\\_36feb6fb-501b-5138-89b3-05d2ceo7f488.html](https://tucson.com/news/local/drought-plan-fight-between-arizona-farms-and-cities-escalates/article_36feb6fb-501b-5138-89b3-05d2ceo7f488.html)

Mosquito- and tick-borne diseases are rising in the U.S. Scientific American. 5/1/2018. (H. Brown)

<https://www.scientificamerican.com/article/mosquito-and-tick-borne-diseases-are-rising-in-the-u-s/>

The Southwest may be deep into a climate-changed mega-drought. The Atlantic. (C. Woodhouse)

<https://www.theatlantic.com/science/archive/2018/12/us-southwest-already-mega-drought/578248/>

Tribal Water Sharing Agreements. Native Water on Arid Lands Podcast. August 18, 2018. (B. Colby)

Urban planners looking to standardize heat maps. Phoenix KJZZ – Arizona Science Desk. (L. Keith)

<https://kjzz.org/content/862106/urban-planners-looking-standardize-heat-maps>





PHOTO CREDIT: DAN FERGUSON

## Next Steps and Future Plans

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

After a hazard mitigation workshop co-organized by CLIMAS and Pima County Office of Emergency Management (OEM), representatives from NOAA—National Weather Service Tucson, CLIMAS, and OEM had conversations about developing a monsoon visualizer. Ben McMahan helped design an internet-based data aggregator and visualizer that combines multiple data sources for precipitation and displays spatial and temporal patterns of precipitation based on user defined inputs. This tool will assist in post-monsoon recovery and cleanup efforts to identify target areas where heavy rains had caused road damage and flooding debris. OEM plans to use the visualizer to target areas for increased flood risk following multiple sequential days of rain. A prototype was developed and adjusted based on input from NWS and OEM colleagues. The public version will be available in summer 2019.

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

Ladd Keith, Tess Wagner, and Ben McMahan are launching an urban heat community of practice with eight partner cities and counties across Arizona and New Mexico. This network will encourage representatives from these government agencies to share how they use urban heat island maps with one another. In addition, a collaborative pilot project is starting in summer 2019 to develop a protocol and collect initial ambient air temperature readings at various park and school sites in the Tucson region. This activity represents a partnership between with the School of Landscape Architecture and Planning and the Water Resource Research Center at the University of Arizona.

### **Evaluating existing and developing new drought indices using modeled soil moisture time series**

Personnel from the U.S. Department of Agriculture—Natural Resources Conservation Service (USDA—NRCS) is interested in CLIMAS research regarding the use of soil moisture modeling to assess drought indices. With continued work and engagement with USDA—NRCS, they will use these models to customize their use of drought monitoring indices. Trevor McKellar and Michael Crimmins have been working with a Las Cienegas Watershed group as well and hope to recommend specific drought indices for their ongoing State of the Watershed monitoring. A prototype R-based Shiny web app is under development. It will function as a drought data explorer and an interactive ‘Drought Playbook’ to select the optimal drought index based on modeling results. Seven USDA—NRCS personnel gave feedback on app development.



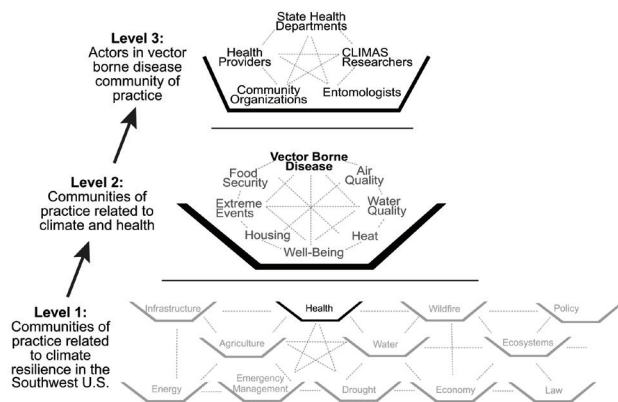
# Evaluation — Methods and Indicators

This year Gigi Owen, Daniel Ferguson, and Ben McMahan completed analysis from the 2012—2018 evaluation cycle. Methods stemmed from program theory-based evaluation. This framework develops and tests an underlying theory of change that articulates how program impacts are generated. In 2012, the core office developed the following theory of change for the CLIMAS program: Engaging with existing and potential climate stakeholders in the Southwest results in usable knowledge. These interactions and information products expand people’s capacities to adapt to climatic shifts and changes. Through a series of semi-structured interviews and focus groups with other CLIMAS investigators between 2012 and 2014, the team further elaborated the program’s theory of change. This iterative process revealed how individual investigators applied the CLIMAS program theory of change in their own projects. Ten logic models were developed to connect project activities to outputs and short-to-intermediate outcomes. In 2016 and 2017, the logic models were reviewed for project outputs and outcomes that were and were not accomplished.

Indicator categories used to demonstrate progress towards outcomes were based on a conceptual typology adapted from Meagher and Martin (2017) and Meagher and Lyall (2013). Specific indicators were developed for each individual project. The five categories of outcome types were:

- » Capacity building outcomes: developing collaborations or providing the information and training necessary to engage in a particular activity
- » Instrumental outcomes: direct influence or use in policy, practice, or decision-making
- » Conceptual outcomes: changes in thinking, raising awareness, or improving understanding of an issue
- » Enduring connectivity outcomes: relationships lasting beyond the course of a project or activity
- » Attitudinal or cultural shifts outcomes: changes in institutional, group, or individual attitudes regarding issues or toward engaging in collaborative activities or knowledge exchange

The evaluation led to an evolution in the theoretical understanding of the CLIMAS program’s operations and contributions to building climate resilience in the Southwest (see Owen et al. 2019). The underlying program theory has changed to show how CLIMAS is part of a growing regional social learning system that is comprised of multiple communities of practice (see Figure 1). CLIMAS helps actively maintain the social learning system in five ways: 1) public communication and outreach about regional climate; 2) convening groups, virtually and physically, who are addressing climate-related issues; 3) providing consulting services regarding climate information; 4) collaborating on research projects with academic and non-academic partners; 5) training the next generation of physical and social scientists to conduct transdisciplinary and use-inspired research.



**FIGURE 1** CONCEPTUAL MODEL OF A CLIMATE RESILIENT SOCIAL LEARNING SYSTEM IN THE SOUTHWEST U.S. SOCIAL LEARNING OCCURS BASED ON RELATIONSHIPS AND INTERACTIONS WITHIN AND ACROSS DIFFERENT COMMUNITIES OF PRACTICE; LEVEL 1 ILLUSTRATES A SAMPLE NETWORK OF COMMUNITIES OF PRACTICE WORKING TO ADDRESS REGIONAL CLIMATE RESILIENCE ISSUES; LEVEL 2 FOCUSES ON THE HEALTH AND CLIMATE COMMUNITY OF PRACTICE, REVEALING EIGHT MORE COMMUNITIES OF PRACTICE, EACH ADDRESSING A SPECIFIC HUMAN HEALTH ISSUE; LEVEL 3 IDENTIFIES GROUPS OF ACTORS WHO WORK WITHIN A REGIONAL VECTOR BORNE DISEASE COMMUNITY OF PRACTICE. (FROM OWEN ET AL. 2019)

The current evaluation cycle (2017—2022) uses similar methods for assessment. However, adjustments have been made based on several lessons learned from the previous cycle. The current evaluation cycle:

- » Includes research partners in annual evaluation interviews as appropriate
- » Reviews logic models annually and updates as needed to address changes in the research process
- » Uses a stakeholder and partner database to track the multiple types of interactions people have with the CLIMAS program and CLIMAS researchers over time

# Evidence of Societal Impact – Evaluation Results

Between 2012–2018, CLIMAS researchers accomplished the following:

**Project Outputs:** Project outputs encompass the tangible ways in which CLIMAS researchers share their research results with scientists, research partners, and the broader public. Most outputs produced were written or orally delivered to project partners, academic audiences, or the public. CLIMAS researchers completed and delivered almost all of the outputs they identified at the project outset and tended to produce more items than anticipated. In total, only four anticipated outputs did not materialize by 2018; these were two academic papers, a suite of outreach materials regarding public health, and a tool to enhance adaptive capacity in the Southwest (see Figure 2).

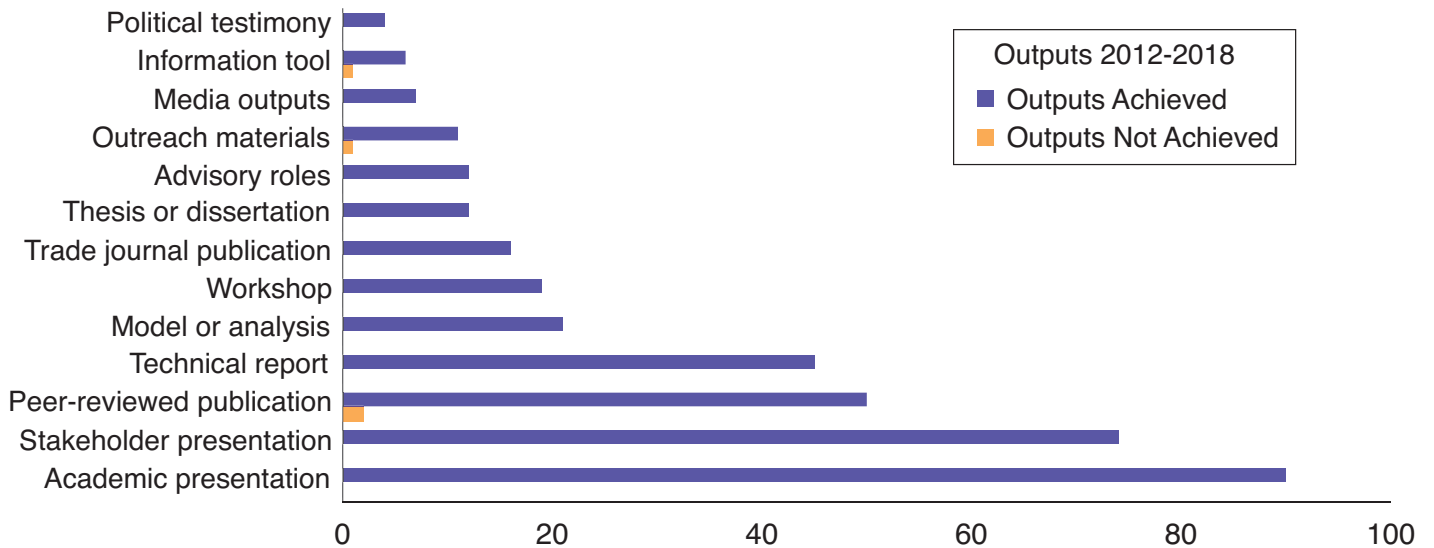


FIGURE 2 CLIMAS PROJECT OUTPUTS ACHIEVED AND NOT ACHIEVED BETWEEN 2012-2018



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**Project Outcomes:** CLIMAS researchers achieved 61 outcomes in total, spread relatively evenly across the five outcome categories defined by Meagher and Martin (2017) and Meagher and Lyall (2013) (see Table 1). Capacity building outcomes were the most frequent (26.2%), followed by instrumental outcomes (21.3%), conceptual outcomes (19.7%), and enduring connectivity outcomes (19.7%). The smallest number of outcomes comprised the attitudinal or cultural type (13.1%).

Outcome Type	Percent of Frequency	Example from a CLIMAS Project
<b>Capacity Building:</b> Developing collaborations, providing information and training necessary to engage in a particular activity	26.2% (n=16)	By attending meetings and trainings with CLIMAS researchers, city government representatives in Arizona and New Mexico explored the potential for and impacts for implementing new water supply reliability tools.
<b>Instrumental:</b> direct influence or use of research in policy, practice, or decision-making	21.3% (n=13)	The New Mexico Department of Transportation used CLIMAS research about the sources and patterns of dust storms to apply for federal funds for improved highway signs, warnings, and road markings. The approved funding was used to build new infrastructure along a stretch of the Interstate—10 Freeway.
<b>Conceptual:</b> changes in thinking, raising awareness, or improving understanding of an issue	19.7% (n=12)	Results from a paleoclimate project with the U.S. Geological Survey and water resource managers increased awareness and understanding of how temperatures impact streamflow and drought in the Colorado River Basin.
<b>Enduring Connectivity:</b> relationships lasting beyond the course of a particular project or activity	19.7% (n=12)	An electric utility company in Tucson, AZ initiated a new collaborative project with CLIMAS researchers on carbon reduction a year after the initial project ended.
<b>Attitudinal or Cultural:</b> changes in attitudes toward engaging in climate research or knowledge exchange activities	13.1% (n=8)	Municipal government representatives in Ciudad Juárez, Mexico shifted from participating to leading a joint heat and health initiative in the New Mexico/Texas/Chihuahua region.

TABLE 1. TYPES OF CLIMAS PROJECT OUTCOMES ACHIEVED BETWEEN 2012-2018



# Societal Impact – Narrative Case Studies

## Community Climate Profiles

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. CLIMAS researchers Alison Meadow, Jeremy Weiss, and Sarah Leroy aim to meet this need by producing climate profiles for communities to support adaptation planning efforts. Profiles include information such as historical/instrumental temperature and precipitation data from 1895 – present at a scale 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 for each of the RCPs, at a regional scale, and a summary of general regional climate impacts. The range of communities that CLIMAS has partnered with on this project is also an accomplishment. This year the research team added tribal communities, emergency managers, and a retirement community to their partner list. The robust approach of this project makes it adaptable to meet the needs of interested partners.

Communities have responded positively to the most local and detailed information available as this helps them develop future action. The climate profile produced for the City of Flagstaff was incorporated directly into their Climate Adaptation and Action Plan (<https://www.flagstaff.az.gov/ClimatePlan>), which will impact approximately 72,000 people. The profile produced for the Town of Oro Valley helped their Office of Emergency Management apply for funding from FEMA to enhance the town’s preparedness for climate and weather-related events. More than 44,000 people stand to benefit from enhanced emergency management. The climate profile for The Highlands at Dove Mountain is informing the community’s Five-Year Trends Planning effort. Close to 2,400 people will be covered by this plan. Adaptation measures in the plan encourage desert-appropriate landscaping, more sustainable golf course management practices, and greater awareness of the physical and mental health impacts of climate change on older adults.



PHOTO CREDIT: B. GAGNON



PHOTO CREDIT: DAVE DUBOIS





PHOTO CREDIT: DAVE DUBOIS

### **Impacts of dust storms to interstate travel and the local trucking industries in NM and AZ**

Convective dust storms have caused numerous automotive accidents in southwestern New Mexico. They are difficult to forecast due to their small sizes and quick development. In 2002, Interstate 10 carried 15,000 trucks per day. Road closures of even a few hours due to dust storms have large economic impacts not only to the trucking companies but also the recipients of the delayed goods and services. By 2040, that amount is projected to reach 25,000. CLIMAS researchers provided evidence to support the development of a convective dust storm warning product by NOAA-NWS. This warning product was implemented in the Phoenix area and has yet to be implemented in southern NM. To help build this warning system, the New Mexico Department of Transportation approved \$40,000 for new equipment to monitor dust conditions along a stretch of highway particularly vulnerable to dust storms.

CLIMAS researcher David DuBois also sends updates from the dust sensor network on the Lordsburg Playa and photos of real-time dust storms to the National Weather Service offices in Albuquerque and El Paso during dust events. The Albuquerque (KOB and KRQE) and El Paso (KVIA) TV weather stations in New Mexico often send this information out to their followers on social media. Combined, these organizations and researchers send out warning messages regarding dust storms and transportation hazards to an audience of more than 31,000 on Twitter.





PHOTO CREDIT: JEREMY WEISS

## Societal Impact – Economic Return

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

Negotiations over the Arizona Drought Contingency Plan in 2018 and 2019 were highly contentious. One area of contention involved the costs of water cutbacks to Pinal County agriculture and what would represent adequate mitigation measures and spending. There was significant disagreement between urban water providers and agricultural interests on these issues. Both sides relied on CLIMAS research findings in their testimony. CLIMAS investigator George Frisvold explained research findings regarding the contributions of agriculture and agribusiness to the Pinal County economy to 25 officials from the Arizona Department of Agriculture, Pinal County government, Maricopa Stanfield Irrigation and Drainage District, Central Arizona Irrigation and Drainage District, and the Arizona Farm Bureau. Representatives wanted to understand the implications of the study and Frisvold received many subsequent requests for information. Economic impact estimates from the study were used in testimony over mitigation funds for Pinal County agriculture. Additionally, Frisvold had phone and email conversations with AZ State Senator Kirsten Engel about the effect of technology requirements on water conservation in response to legislative debates over the Drought Contingency Plan. In the Arizona Drought Contingency Plan approved by the state legislature and signed by the state governor, \$9 million was appropriated for groundwater infrastructure projects to mitigate effects of surface water shortages.





PHOTO CREDIT: JEREMY WEISS

## CLIMAS 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 U.S. These projects 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. 33)

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

- » A Colorado River Shortage Declaration: Planning, Responses, and Consequences (p. 29)
- » Sectoral Impacts of Drought and Climate Change (p. 30)

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

- » The Southwest Climate Outlook (p. 11)
- » Southwest Climate Podcasts (p. 12)
- » Southwest Climate Information Hubs (p. 12)

### **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. 27)
- » Exploring the Use of Climate and Remote Sensing Data to Support Drought Monitoring across the Southwest U.S. (p. 27)

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

- » Adaptation Strategies for Water and Energy Sectors in the Southwest (p. 26)
- » Adaptation to Climate Variability and Change: Markets, Policy, Technology, and Information (p. 28)
- » An Assessment of Drought and Climate Vulnerability and Resilience in the Rio Grande Basin in New Mexico (p. 28)



# Education and Training

## **Connecting environmental science and decision making: A graduate seminar**

Scientific knowledge can be critical for dealing with complex, socially relevant environmental issues, although much 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, taught by CLIMAS Investigator Connie Woodhouse and 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, co-production 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, such as resource management professionals, planners, policy makers, NGOs, and the general public.

## **Environment & Society Fellowship Program**

The Environment & Society Fellowship was created in 2013 by members the Climate Assessment for the Southwest program, with support from the University of Arizona Office of Research, Discovery, and Innovation. The fellowship, managed by Investigators Gigi Owen and Ben McMahan, provides training and funding for graduate students to practice use-inspired research and science communication. Since its inception, the Fellowship program has funded 24 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 have received approximately \$500,000 in grant awards to extend their work beyond the one-year Fellowship projects. <https://www.climas.arizona.edu/education/fellowship-program>

## 2018—2019 Environment & Society Fellows:

### **Rights and resistance: Historical and contemporary struggles for water and sovereignty in Owens Valley, CA—Sophia Layser Borgias, PhD Candidate, School of Geography and Development**

The water rights of the Owens Valley Paiute (Nüümü) remain legally disputed to this day since the federal government withdrew, sold, and traded tribal lands to the Los Angeles Department of Water and Power. This project examines how public, private, and tribal interests have been weighed and reconciled in decisions about Owens Valley land and water allocation over more than a century of shifting laws, policies, and environmental conditions. Methodologically, the project design reverses the gaze of the research to address the concerns of indigenous communities and engage community actors throughout the research process. The CLIMAS Environment and Society Fellowship has supported the initial phases of this participatory research and outreach process, supporting efforts to produce results relevant to local community struggles and regional policy-making as well as scholarly debates.

### **Understanding Farmers' Choices, Trade-Offs and Barriers for Selecting Land Management Practices in Northern Ghana—Marie Blanche Roudaut, PhD Candidate, Arid Lands Resource Sciences**

This research focuses on the semi-arid region of northern Ghana (Upper East Region) where the livelihoods and agro-ecosystems on which farmers and agro-pastoralists depend on are threatened by land degradation. This scoping research focused on how local/indigenous and scientific knowledges can be integrated to provide a more comprehensive understanding of the complex and dynamic socio-ecological process that lead to land degradation. The land degradation indicators developed by integrating these different knowledges will enable land users to reliably monitor changes themselves without external assistance and support the adoption of more sustainable land management practices. A final objective is to help design monitoring initiatives that are better-suited to the end-users and therefore more likely to results in livelihood improvement.



PHOTO CREDIT: SOPHIA BORGIAS



PHOTO CREDIT: STEPHANIE DOERRIES

**Use-inspired science for groundwater governance: Science production, transfer and use in southern Arizona—Tamee Albrecht, PhD Student, School of Geography and Development**

As climate change and variability make surface water sources less reliable, groundwater supplies will become increasingly critical for human sustainability, especially in arid regions. The need for effective science-based management of these precious resources is imminent. This scoping project produced findings regarding (1) the status of groundwater science and policy in southern Arizona, (2) barriers in the science-policy process, and (3) persistent information needs in the Santa Cruz Active Management Area (SCAMA). This project revealed that processes for collection, transfer, and use of groundwater science in management are generally positive and successful in the SCAMA. Findings inform an upcoming dissertation project as well as information products for water managers in southern Arizona.

**Estimating survival and abundance of the endangered Sonoran pronghorn—Stephanie Doerries, PhD Candidate, School of Natural Resources and the Environment**

Understanding the impacts of climate change, human activity, and habitat fragmentation on large herbivore populations is essential to facilitate recovery of endangered species such as the Sonoran pronghorn, a subspecies of American antelope unique to the Sonoran Desert. Wildlife managers with limited resources, including the Arizona Game and Fish Department (AZGFD), U.S. Fish and Wildlife Service, U.S. National Park Service, U.S. Air Force, and U.S. Marine Corps, face the problem of accurately estimating basic population parameters such as abundance and survival of Sonoran pronghorn. Without quality estimates, managers struggle to accurately assess the effects of climate change, human activity, and habitat fragmentation on Sonoran pronghorn recovery, as well as the efficacy of costly recovery efforts implemented after a year of severe drought in 2002. To address these challenges, Doerries collaborated with AZGFD to improve estimates of abundance and survival. Her analysis and methods for estimating pronghorn are being used by AZGFD.

## 2019—2020 Environment & Society Fellows

- » **Alma Anides Morales**, a Master's student in Soil, Water, and Environmental Science, is collaborating with Cochise Health and Social Services (CHSS) to sample and analyze untreated sewage flows in Naco, Arizona, a town of about 1,000 residents on the U.S.—Mexico border. The research seeks to determine potential environmental impacts and human health risks.
- » **Nupur Joshi**, a PhD student in the School of Geography and Development, is researching water availability, quality, and affordability in low-income settlements in Nairobi, Kenya. She collaborates with women community members, Nairobi County government officials, non-profit groups, and “water cartel” (informal water infrastructure systems) representatives to conduct a spatial analysis of these informal water infrastructures to better understand how issues regarding water access impact women's health.
- » **Sean Schrag-Toso**, a Master's student in Hydrology and Atmospheric Sciences, is analyzing isotope ratios and the geochemistry of springs to create a conceptual model of groundwater flow. This model will inform current monitoring efforts of a citizen science group in Sonoita Creek Watershed in southeastern Arizona. Data will aid the Patagonia Town Council in making water use management decisions.
- » **Norma Villagómez-Márquez**, a PhD student in Soil, Water, and Environmental Science, is examining the presence of contaminants in roof-harvested rainwater, an increasingly common practice used to address drought and climate change impacts. Working with Project Harvest: Be Informed, Grow Smarter, she encourages community members to be more engaged with issues around the health of their harvested rainwater and its impact on soil and plants. For her project, she will create an illustrated children's book to spark interest in water conservation alternatives and rainwater harvesting.



# Appendix A: Publications

- \*\*Bickel A, D Duval, and G Frisvold. 2018. Contribution of on-farm agriculture and agribusiness to the Pinal County economy. Tucson: University of Arizona Cooperative Extension. <https://cals.arizona.edu/arec/publication/contribution-farm-agriculture-and-agribusiness-pinal-county-economy>
- A hypothetical 300,000 acre-foot water cutback could lead to the following losses in Pinal County: (a) \$63.5—\$66.7 million loss in gross farm-gate sales, (b) \$94—\$104 million loss in total county sales, (c) \$31.7—\$35 million loss in county value added, and (d) 270—480 jobs lost. Local irrigation districts and the Arizona Department of Agriculture requested this information. Study report was posted on the Arizona Farm Bureau and Pinal County government websites. The Arizona Municipal Water Users Association developed a briefing memo using study results for their positions on the Drought Contingency Plan. Nine news articles cited this study and its findings.
- Colby B and R Isaaks. 2019. Water Trading: Innovations, Modeling Prices, Data Concerns. *Journal of Contemporary Water Research and Education* 165(1):76—88. DOI: 10.1111/j.1936-704X.2018.03295.x
- Cvitanovic C, M Howden, R Colvin, A Norström, AM Meadow, P. Addison. 2019. Maximising the benefits of participatory climate adaptation research by understanding and managing the associated challenges and risks. *Environmental Science & Policy* 94:20—31.
- \*\*Frisvold G. 2018. Improving Water Footprint Calculations Using Local Agronomic and Environmental Data. Technical Report prepared for Barilla Company.
- Using better local data on precipitation and evapotranspiration it was found that the water footprint of durum wheat production in Arizona was much lower than previously estimated. There is increasing interest among private corporations and environmental NGOs in measuring water footprints for producing a variety of goods. The research considers how and why durum wheat production can be sustainable in the Lower Colorado Delta. It also demonstrates that the water footprint is an incomplete metric of water conservation and environmental impacts.
- Ghodsizadeh Z. 2018. Modeling of dust emission for a crusted surface. Master's of Science Thesis, New Mexico State University.
- Gonzalez P, GM Garfin, DD Breshears, KM Brooks, HE Brown, EH Elias, A Gunasekara, N Huntly, JK Maldonado, NJ Mantua, HG Margolis, S McAfee, BR Middleton, and BH Udall. 2018. Southwest. In *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II*. DR Reidmiller, CW Avery, DR Easterling, KE Kunkel, KLM Lewis, TK Maycock, and BC Stewart, eds. U.S. Global Change Research Program, Washington, DC. DOI: 10.7930/NCA4.2018.CH25
- Isoe J, LE Koch, YE Isoe, AA Rascon, HE Brown, BB Massani, RL Miesfeld. 2019. Identification and characterization of the mosquito-specific eggshell organizing factor in *Aedes aegypti* mosquitoes. *PLoS Biology* 17(1):e3000068. DOI: 10.1371/journal.pbio.3000068
- 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* 52(2):487—504. DOI: 10.1111/1752-1688.12619
- Konyar K and G Frisvold. 2019. Climate Policies as Water Policies. In *Applied Methods for Agriculture and Natural Resource Management*. S Msangi and D MacEwan, eds. *Natural Resource Management and Policy* 50:189—211. DOI: 10.1007/978-3-030-13487-7\_11
- Lemos MC, JC Arnott, NM Ardoin, K Baja, AT Bednarek, A Dewulf, C Fieseler, KA Goodrich, K Jagannathan, N Klenk, KJ Mach, AM Meadow, R Meyer, RH Moss, L Nichols, KD Sjoström, M Stults, E Turnhout, C Vaughan, G Wong-Parodi, and CA Wyborn. 2018. To co-produce or not to co-produce. *Nature Sustainability* 1(12): 722.
- LeRoy A, AM Meadow, and J Weiss. 2018. Climate-Related Hazards in the Town of Oro Valley, Arizona. CLIMAS Community Climate Profiles. Tucson, University of Arizona.
- Meadow AM, S LeRoy, J Weiss, and L Keith. 2018. Climate Profile for The City of Flagstaff, Arizona. CLIMAS Community Climate Profiles. Tucson, University of Arizona.
- Meadow AM, S LeRoy, J Weiss, and L Keith. 2019. Climate Profile for The Highlands at Dove Mountain. CLIMAS Community Climate Profiles. Tucson, University of Arizona.

- Owen G, DB Ferguson, and B McMahan. 2019. Contextualizing climate science: applying social learning systems theory to knowledge production, climate services, and use-inspired research. Climatic Change DOI: 10.1007/s10584-019-02466-x.
- Roach M, E Austhof, V Berisha, HE Brown, D Carr, L Harlow-Smith, D Hondula, and K Snyder. (2018). Addendum to the Arizona Climate and Health Adaptation Plan. A report prepared for the United States Centers for Disease Control and Prevention Climate-Ready States and Cities Initiative.
- Weiss J, M Crimmins, D DuBois, and G Garfin. 2018. El Niño 2018—2019? An Overview of What It Might Mean for New Mexico. CLIMAS Climate Fact Sheet. Tucson, University of Arizona.
- Weiss J, M Crimmins, G Garfin, and P Brown. 2018. El Niño 2018—2019? An Overview of What It Might Mean for Arizona, University of Arizona Cooperative Extension Climate Fact Sheet. Tucson, University of Arizona. <https://cals.arizona.edu/research/climategem/sites/cals.arizona.edu.research.climategem/files/ENwatch20182019overview.pdf>
- \*\*Weiss J, S LeRoy, AM Meadow, and C Castro. 2018. Climate Change Impacts on the North American Monsoon: Summary for the Tohono O’odham Nation. CLIMAS Community Climate Profiles. Tucson, University of Arizona.
- This report summarizes observed and projected changes in the North American monsoon that are particularly relevant to emergency managers in the Tohono O’odham Nation of southwestern Arizona. The audience was the Tohono O’odham Nation Office of Emergency Management. The report responded directly to questions from The Tohono O’odham Nation OEM regarding changes to the North American Monsoon and was intended to help support grant-writing efforts of that office.
- Weiss J, MB Roudaut. 2018. Initial Assessment of Daily Minimum Temperature from Data Loggers in Routson Orchards. Climate Assessment for the Southwest, University of Arizona.



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## Appendix B: Current CLIMAS Projects

### Is adaptation mal-adaptation: an assessment of mosquitoes and water harvesting

**CLIMAS Investigators:** Heidi Brown, Ladd Keith, Valerie Madera-Garcia

**Research Partners:** Tucson Water; Pima County Vector Control

**Additional Support:** Pacific Southwest Regional Center of Excellence for Vector-Borne Disease Research at the University of California—DHHS Center for Disease Control and Prevention

Rainwater harvesting design techniques are heralded as tools for building a sustainable community and resilience against climate change impacts. When rainwater harvesting strategies fall into disrepair or are designed improperly, they may inadvertently become sources of mosquitoes. We hypothesize that well-maintained green infrastructure design strategies have the greatest impact on conservation while limiting the negative consequences of mosquitoes. If green infrastructure is to be used as an adaptation technique, then it is important to better understand when it works best. Partnering with Tucson Water, which is responsible for some green infrastructure installation and Pima County Vector control represents two key stakeholders in addressing whether this is mal-adaptation.

**Deliverables:** 1) *Presentation:* Is adaptation mal-adaptation: an assessment of mosquitoes and water harvesting. PacVec Annual Meeting. UC Davis. January 2019.

### Identifying gaps in stakeholder needs regarding the climate-health connection

**CLIMAS Investigators:** Heidi Brown, Dan Ferguson, Erika Barrett

**Research Partners:** Arizona Department of Health Services; Arizona State University

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

As part of the Climate-Ready States and Cities Initiative, the CDC engaged 16 states and 2 large cities to implement a 5-step program Building Resilience Against Climate Effects (BRACE) in 2009. The program aimed to help communities prepare for the health effects of climate change. As BRACE ends, the CDC is now supporting the monitoring and evaluation of the efforts developed under BRACE: Climate and Health Adaptation Monitoring Program (CHAMP). To support these monitoring and evaluation efforts, we are working to map the Arizona network of climate/health advocates, to identify gaps that stakeholders need regarding the climate-health connection, and to develop strategies to better support these efforts. The goal of this project is to identify how academics working on climate and health issues can better serve the stakeholders who are actively working on climate/health adaptation planning. This information will help inform adaptation and mitigation plans for the state of Arizona and help build partnerships throughout the state with CLIMAS and other groups.

**Deliverables:** 1) *Report:* Roach M, E Austhof, V Berisha, HE Brown, D Carr, L Harlow-Smith, D Hondula, and K Snyder. (2018). Addendum to the Arizona Climate and Health Adaptation Plan. A report prepared for the United States Centers for Disease Control and Prevention Climate-Ready States and Cities Initiative. 2) *Presentations:* Six presentations about mosquito vectors in Arizona and public health impacts of climate change to academic, stakeholder, and public audiences.

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

**CLIMAS Investigators:** Bonnie Colby, George Frisvold, Connie Woodhouse, Gregg Garfin, Rowan Isaaks, Ryan Young, Emily Joiner

**Research Partners:** U.S. Bureau of Reclamation; U.S. Dept. of Agriculture; New Mexico Office State Engineer; University of Nevada Reno; University of Colorado; Sonoran Institute; Nature Conservancy; Walton Family Foundation

**Additional Support:** NOAA Regional Climate Centers; NOAA—Sectoral Applications Research Program; U.S. Bureau of Reclamation; Walton Family Foundation; Sonoran Institute

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 these tools to enhance supply reliability. 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. 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, agreements which improve regional resilience. CLIMAS researchers are providing technical expertise to stakeholder groups, NGOs, tribal leaders and public agencies to facilitate voluntary water sharing agreements which improve regional resilience.

**Deliverables:** 1) *Workshop:* Native Waters Arid Lands Tribal Summit, Reno, NV. October 2018. 140 attendees. 2) *Presentations:* Three presentations to stakeholder audiences addressing the climate effects on water resources and resilience strategies. 3) *Media:* Guest appearance on a podcast. Tribal Water Sharing Agreements. Native Water on Arid Lands Podcast August 18, 2018.

## Evaluating existing and developing new drought indices using modeled soil moisture time series

**CLIMAS Investigators:** Michael Crimmins, Marcel Schaap, Craig Rasmussen, Daniel Ferguson, Trevor McKellar

**Research Partners:** The Nature Conservancy; Las Cienegas Watershed Group

**Additional Support:** NASA—Space Grant; NIDIS—National Integrated Drought Information System

Our initial project study area is focused on the Las Cienegas National Conservation Area in partnership with the Nature Conservancy (TNC) to examine longer-term drought impacts in a multi-use, Bureau of Land Management NCA. We are working with TNC to develop modeled long-term soil moisture estimates to examine with long-term vegetation monitoring data. This will allow us to assess the impacts of precipitation variability and temperature changes on vegetation production and mortality and identify optimal drought monitoring metrics. We are finding that traditional, simple drought indices like the Standardized Precipitation Index capture complex variability in soil moisture reasonably well at shallow depths. This allows us to recommend using an index like the 2-month SPI to anticipate drought impacts to shallow rooted rangeland vegetation. We are also finding that precipitation variability in winter and summer wet seasons can be used to anticipate soil moisture variability at deeper depths many months later and used as a sort of drought forecasting tool.

A preliminary accomplishment has been in presenting to U.S. Department of Agriculture—Natural Resources Conservation Service (USDA—NRCS) field personnel and establishing some interest in our idea of using soil moisture modeling to assess drought indices. With continued work and engagement with USDA—NRCS we may be able to convince them this is a good strategy to use across their land management units, allowing them to customize their use of drought monitoring indices. We have been working with the Las Cienegas Watershed group as well and may be able to recommend specific drought indices for their ongoing State of the Watershed monitoring. This will become clearer by next spring if they adopt any of our recommendations.

**Deliverables:** 1) *Web App:* A prototype R based Shiny web app is under development. This web app will function as drought data explorer and an interactive 'Drought Playbook' to select the optimal drought index based on modeling results. 2) *Workshop:* Developing a drought monitoring playbook for Arizona rangelands, March 7th, 2019. Workshop held at USDA—NRCS Office in Tucson, AZ. 3) *Presentations:* Six presentations to stakeholders, project partners, and public audiences.

## Exploring the use of climate and remote sensing data to support drought monitoring across the Southwest U.S.—DroughtView

**CLIMAS Investigators:** Michael Crimmins and Jeremy Weiss

**Research Partners:** University of Arizona—School of Natural Resources; University of Arizona—College of Agriculture and Life Sciences Communications & Cyber Technologies



**Additional Support:** NOAA—National Weather Service: Advanced Hydrologic Prediction Service; NIDIS—National Integrated Drought Information System; NOAA—Sectoral Applications Research Program; U.S. Department of Agriculture Hubs; Arizona Remote Sensing Center; Arizona Space Grant Consortium; NASA U.S. Geological Survey—Land Processes Distributed Active Archive Center; PRISM Climate Group; University of Arizona Water, Environmental & Energy Solutions

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 operational remote-sensing based operational 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 targeting at detecting drought conditions. DroughtView builds on the success of a precursor effort called RangeView that was developed with the guidance of agriculturists and resource managers with a need for environmental monitoring data. The tools in DroughtView are currently 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.

**Deliverables:** 1) *Decision Support Tool:* DroughtView <https://climate.arizona.edu/droughtview/> 2) *Presentations:* Two presentations to stakeholder and academic audiences.

## Impacts of climate extremes to interstate and local trucking industry across New Mexico and Arizona

**CLIMAS Investigators:** David DuBois, Antonio Arredondo, Zahra Ghodsizadeh, Jaylen Fuentes, Josue Gutierrez, Octavio Nayares, Stan Engle, Merrill Bean, and Michael DeAntonio

**Research Partners:** National Weather Service, Santa Teresa and Phoenix offices; U.S. Bureau of Land Management, Las Cruces; New Mexico Department of Transportation; Mesilla Valley Transportation

**Additional Support:** NOAA—National Weather Service

Transportation along our nation’s highways forms a basis for our economy, moves our food from place to place, and serves to connect our communities. Extreme weather impacts our transportation system in many ways and for this project, particularly during drought, we focus on dust storms. Our project goal is the increase the resilience of drivers during these events. We start our project in southwestern New Mexico along interstate 10 where lives have been lost as a result of dust storms. Our partners at the start the project 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. Our project serves to assist them in characterizing and documenting the climatic and visual conditions that exist during these storms through interviews with drivers and road managers, in addition to time-lapse camera imagery and dash cams. Providing resilience to extreme weather events is a critical step in improving our lives across the nation. Building on existing partnerships between CLIMAS and state transportation managers from NM and AZ we address a long-term problem that takes lives every year on our highways.

**Deliverables:** 1) *Master’s Thesis:* Ghodsizadeh Z. 2018. Modeling of dust emission for a crusted surface. New Mexico State University: Las Cruces, NM. The goal of this study was to improve the representation of the magnitude, frequency, and particle size distribution of dust emission flux from crusted surfaces. 2) *Workshop:* Southern NM Fugitive Dust Symposium and Workshop, April 17, 2019 in Las Cruces, NM. 3) *Presentation:* One presentation at the American Meteorological Society Annual Meeting, January 9, 2019, summarizing the work being done to characterize dust hazards on Interstate—10 and how it can be used for transportation management. 4) *Video:* NOAA RISA’s CLIMAS Team: Science Clears the Air in Dust Storm Response <https://youtu.be/ENyIO-coRKg>

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

**CLIMAS Investigators:** George Frisvold and Xiaoting Wu

**Research Partners:** U.S. Department of Agriculture—Natural Resource Conservation Service; University of Arizona—Water Resources Research Center; Yuma County Water Users Association

**Additional Support:** U.S. Department of Agriculture—National Agricultural Statistics Service; U.S. Department of Agriculture—Economic Research Service; U.S. Bureau of Reclamation; Cotton Incorporated

This project examines the role of water management information and irrigation technologies in agricultural adaptation to climate variability and change in the 17 westernmost U.S. 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, (c) how climate affects choice of irrigation technologies. The project conducts statistical analysis to examine how factors such as farm size, water costs, and drought affect demand for water management information. For Arizona specifically the project examines trends in 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”). It also considers the inverse of water productivity, the water footprint, which measures water use per unit of output.

**Deliverables:** 1) *Publications:* Konyar K and G Frisvold. 2019. Climate Policies as Water Policies. In *Applied Methods for Agriculture and Natural Resource Management*. S Msangi and D MacEwan, eds. *Natural Resource Management and Policy* 50:189—211. DOI: 10.1007/978-3-030-13487-7\_11. Climate mitigation policies (e.g. cap and trade, carbon taxes) can significantly reduce agricultural water use, while mitigation policies combined with domestic offsets for carbon sequestration are a potential solution to the hypoxic “dead zone” in the Gulf of Mexico.

Frisvold G. 2018. Improving Water Footprint Calculations Using Local Agronomic and Environmental Data. Technical Report prepared for Barilla Company. Using better local data on precipitation and evapotranspiration it was found that the water footprint of durum wheat production in Arizona was much lower than previously estimated. There is increasing interest among private corporations and environmental NGOs in measuring water footprints for producing a variety of goods. The research considers how and why durum wheat production can be sustainable in the Lower Colorado Delta. It also demonstrates that the water footprint is an incomplete metric of water conservation and environmental impacts.

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

**CLIMAS Investigators:** George Frisvold, Xinye Wu, and Chengyang Hu

**Research Partners:** University of Arizona—Department of Agricultural and Resource Economics; National Climatic Data Center; NIDIS—National Integrated Drought Information System; University of Arizona—Water Resources Research Center; U.S. Bureau of Reclamation; U.S. Department of Agriculture; Arizona Department of Water Resources; Central Arizona Irrigation Districts

**Additional Support:** NIDIS—National Integrated Drought Information System; NOAA—Regional Climate Center, U.S. Department of Agriculture Hubs; U.S. Global Change Research Program—National Climate Assessment; U.S. Bureau of Reclamation

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 U.S. 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 will assess how stakeholder groups currently use Colorado River supply forecasts in decision-making and what contingencies they are making 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.

According to the 2007 *Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lakes Powell and Mead* a near-term shortage declaration would result in more than \$20 million in lost personal income (employee compensation + proprietor’s income). These losses are likely to be concentrated in rural communities. One adaptation that farmers can make is to switch to exhaustible groundwater supplies. While this may reduce short-term adjustment costs, it may reduce the sustainability of agricultural production in Central Arizona.

This project estimated the economic impacts of changes in wheat, alfalfa, and cotton acreage resulting from a hypothetical reduction of 300,000 acre-feet of irrigation water for Pinal County agriculture. This was meant to capture approximate potential effects of water cutbacks under the state Drought Contingency Plan. Changes in acreage, agricultural production, and broader impacts to the Pinal County economy were estimated under different following scenarios.



**Deliverables:** 1) *Publication:* Bickel A, D Duval, and G Frisvold. 2018. Contribution of on-farm agriculture and agribusiness to the Pinal County economy. Tucson: University of Arizona Cooperative Extension. <https://cals.arizona.edu/arec/publication/contribution-farm-agriculture-and-agribusiness-pinal-county-economy> A hypothetical 300,000 acre-foot water cutback could lead to the following losses in Pinal County: (a) \$63.5–\$66.7 million loss in gross farm-gate sales, (b) \$94–\$104 million loss in total county sales, (c) \$31.7–\$35 million loss in county value added, and (d) 270–480 jobs lost. Local irrigation districts and the Arizona Department of Agriculture requested this information. Study report was posted on the Arizona Farm Bureau and Pinal County government websites. The Arizona Municipal Water Users Association developed a briefing memo using study results for their positions on the Drought Contingency Plan. 2) *Media coverage:* Nine news articles cited this study and its findings.

## Sectoral Impacts of Drought and Climate Change

**CLIMAS Investigators:** George Frisvold and Xiaoting Wu

**Research Partners:** NIDIS—National Integrated Drought Information System; Arizona Department of Water Resources; Arizona Department of Forestry and Fire Management; Gila River Indian Community; University of Arizona—Federally Recognized Tribes Extension Program

**Additional Support:** NOAA—Regional Climate Center, U.S. Department of Agriculture Hubs, U.S. Geological Survey; U.S. Bureau of Reclamation; U.S. National Park Service

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. Project activity on this grant was largely meeting and interacting with stakeholder groups to collaboratively develop three (3) grant proposals for the upcoming project year: 1) An analysis of the economic impacts to the Graham and Greenlee County economies from reduced agricultural production in the event of hypothetical reduced water supply scenarios; 2) An analysis of methods to value agricultural water and develop voluntary acquisition programs; 3) Economic Impacts on Drought on Agriculture, Recreational Tourism, and Rural Communities.

## An assessment of drought and climate vulnerability and resilience in the Rio Grande basin in New Mexico

**CLIMAS Investigators:** Christina Greene, Ben McMahan, and Daniel Ferguson

**Additional Support:** NIDIS—National Integrated Drought Information System

This project assesses drought and climate vulnerabilities and resilience from the perspective of New Mexico residents and experts. The 2018 New Mexico Drought Plan calls for more in-depth assessments of New Mexico drought vulnerabilities and this project contributes to this need by identifying stakeholder concerns and drought research priorities along the Rio Grande Basin. This drought and climate vulnerability assessment engages with areas of concern identified by the New Mexico Drought Task Force, including water, economy, fire, recreation, health, agriculture, and the environment. This project provides an expansion of CLIMAS activities in New Mexico. With initial engagement with state officials, the NM Drought Task Force Team, and the NM Drought Monitoring Group, this project will expand CLIMAS's network of collaborators and stakeholders in New Mexico and identify emergent drought research priorities that feed into subsequent years of CLIMAS/NIDIS project work.

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

**CLIMAS Investigators:** Ladd Keith, Ben McMahan, Tess Wagner

**Research Partners:** Bernalillo County; City of Albuquerque; City of Buckeye; City of Avondale; City of Las Cruces; City of Santa Fe; City of Tucson; City of Phoenix; Dona Ana County; Pima Association of Governments; Arizona State University; Sonoran Institute; Trust for Public Land; Green Infrastructure/Low Impact Development Working Group; Urban Land Institute

The impacts of the urban heat island (UHI) and extreme heat events are well documented, including increases in heat-related public health issues, stresses on urban ecology, and energy usage to mitigate the higher temperatures. Increases in urban heat 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. Our partner cities and county have indicated they want to use the maps to help inform the conservation of natural and agricultural lands, prioritize shade interventions along trails and street corridors, and reduce the amount of parking lots required.

**Deliverables:** 1) *Urban Heat Island maps:* These maps were produced for the cities of Avondale, Buckeye, and Santa Fe, and Dona Ana County. 2) *Media coverage:* Guest appearance on KJZZ Phoenix Arizona Science Desk radio program, April 5, 2019. 3) *Presentations:* Eight presentations with partners and stakeholder and academic audiences.

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

**CLIMAS Investigators:** Ben McMahan, Michael Crimmins, Patrick Bunn, Gabe McGowan, Hsin-I Chang

**Research Partners:** National Weather Service, Tucson; Pima County Office of Emergency Management

**Additional Support:** Monsoon precipitation is difficult to forecast and analyze. Daily and seasonal precipitation are commonly used, but other sources of data (including citizen science monitoring) could be integrated into a higher resolution and more accurate monsoon assessment framework. Tucson has dozens of observations collected by 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 would also pilot-test a process by which southwestern data networks could be combined into an integrated monsoon assessment database. After a hazard mitigation workshop we co-organized with Pima County OEM, we had conversations about use of our monsoon visualizer to aid and assist in post monsoon (extreme rainfall) recovery and cleanup efforts, to identify target areas where heavy rains had caused likely impacts in terms of road damage, debris removal, and target areas for increased flood risk following multiple sequential days of rain. We also started conversations with CLIMAS colleagues looking at green infrastructure and mosquito risk, to connect our assimilated data to their research question, to better identify areas of likely standing water.

**Deliverables:** 1) *Workshop:* Pima County Multi-Jurisdictional Hazards Workshop. Visualization & Analysis Tools for the North American Monsoon. Integrating Citizen Science Data and Observations. October 2018. Tucson, AZ. 2) *Presentations:* Two presentations to stakeholders and research partners.

## Environmental Risks and Built Environment in the Borderlands of the Southwest

**CLIMAS Investigators:** Ben McMahan, Genesis Rodriguez, Leah Bishop, Ramon Driesen, Leslie Pilli

**Research Partners:** Arizona Department of Environmental Quality; Asociación por Revegetación en Ambos Nogales; Sonora Environmental Research Institute; Borderlands Restoration



**Additional Support:** National Weather Service, Tucson; U.S. Environmental Protection Agency; Border Environment Cooperation Commission/Border 2020; Agnese Nelms Haury—Program in Environment and Social Justice

There are numerous avenues for collaborative research projects and outreach in the borderlands region, and this project provides a mechanism to develop new research and engagement, as well as to connect CLIMAS expertise to existing project work. Topics emphasize climate and health (environmental risks and air quality), small scale computing, technology, and citizen science monitoring of environmental phenomena, emergent CLIMAS specific outreach and network development, and small-scale solar feasibility.

**Deliverables:** 1) *Conference:* Environmental Meeting in Nogales, Sonora, at Instituto Tecnológico de Nogales, November 2018. 2) *Demonstrations:* Two workshop demonstrations to show the assembly of a low-cost air quality sensor network for environmental monitoring. 3) *Presentations:* Two presentations about general climate change research to public and academic audiences. 4) *Media:* Two news articles written about these events and projects.

## The Lower San Pedro Conservation Collaborative: Stakeholder Engagement on Climate and Environmental Vulnerability

**CLIMAS Investigators:** Ben McMahan, Daniel Ferguson, Michael Crimmins

**Research Partners:** U.S. Bureau of Land Management; U.S. Bureau of Reclamation; Saguaro National Park; U.S. Forest Service Coronado National Forest; U.S. Forest Service Fish and Wildlife Service; Arizona Department of Forestry and Fire Management; Arizona Game and Fish Department; Arizona State Land Department; Cochise County; Graham County; Pima County; Pinal County; San Carlos Apache Tribe; Aravaipa Property Owners Association; Cascabel Conservation Association; Lower San Pedro Watershed Alliance; Audubon; Sierra Club; Sky Island Alliance; The Nature Conservancy; Archeology Southwest; ASARCO; Salt River Project

This project focuses on drought and climate related vulnerability in the lower San Pedro and upper Gila watersheds. It includes collaborative research and engagement with a mix of stakeholders who have a shared interest in better understanding of climate risks, and the role that drought and climate vulnerability might play in shaping future climate risks. We ask, what would a local-to-regional perspective on drought/climate vulnerability look like? How might that inform a drought early warning system? The project connects to rural questions about drought and climate vulnerability at the regional scale. These case studies illustrate the complexity of drought early warning systems, reveal the role of drought vulnerability, and connect to locally salient decisions and planning.

## Greenhouse Gas Reduction Collaboration

**CLIMAS Investigators:** Ben McMahan, Andrea Gerlak

**Research Partners:** Tucson Electric Power

**Additional Support:** Unisys; Tucson Electric Power

Tucson Electric Power contracted with us, based on the results of our last research partnership with them, to explore plausible scenarios for GHG/carbon reduction in their energy portfolio. These scenarios focus on internal data regarding the economics of these portfolio decisions, external data that might be affect these decisions, and a critical assessment of the overall process to ensure robust data and models are used in scenario development.

## Community Climate Profiles

**CLIMAS Investigators:** Alison Meadow, Jeremy Weiss, Ladd Keith, Sarah Leroy

**Research Partners:** Adaptation International

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 addresses the lack of access to appropriate climate change information by producing 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 a scale

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 for each of the RCPs, at a regional scale, and a summary of general regional climate impacts

**Deliverables:** 1) *Reports:* Four climate profiles were produced for: the Tohono O’odham Nation Office of Emergency Management; City of Flagstaff, AZ; Town of Oro Valley, AZ; and the Highlands at Dove Mountain community. 2)

*Presentations:* Two presentations were given to stakeholders and research partners. 3) *Media coverage:* This project was covered in one online news article.

## Southwest Tribal Data Summit: Partnering with Southwest Indigenous Communities to Identify Data

**CLIMAS Investigators:** Stephanie Rainie, Daniel Ferguson, Sarah Leroy

**Research Partners:** Colorado State University; University of North Carolina; Albuquerque Area Southwest Tribal Epidemiology Center; Inter Tribal Council of Arizona

**Additional Support:** NIDIS—National Integrated Drought Information System; U.S. Indigenous Data Sovereignty Network

As Indigenous communities in the U.S. and around the world confront ongoing climate hazards (e.g., drought) and plan for future problems related to climate change such as threats to human health, a variety of challenges have arisen related to the data necessary to support decisionmaking. 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 decisionmaking for Native nations, including decisions related to community climate resilience. That dearth of data can be a significant barrier for political leaders and resource management practitioners who need to track developing trends as well as current conditions to inform decisions about access to and use of natural resources such as grasslands for livestock or adaptation planning to sustain and improve community health. As Native nations seek to utilize the best available data and information to build climate resilience and healthy, sustainable communities, issues around data relevance, ownership, access, possession, and control arise.

The University of Arizona’s CLIMAS program and the Native Nations Institute, in conjunction with the U.S. Indigenous Data Sovereignty Network, hosted “Supporting Tribal Data Governance for Community Resilience: A Southwest Indigenous Climate Summit” in September 2018. Participants included tribal leaders and community members, academics, private foundations, and federal government officials. This event fostered discussion about unique issues surrounding Indigenous data sovereignty, tribal data governance, and Indigenous knowledge related to climate resilience efforts within Southwest Indigenous communities.

**Deliverables:** 1) *Workshop:* Supporting Tribal Data Governance for Community Resilience: A Southwest Indigenous Climate Summit. September 2018, Tucson, AZ. 2) *Presentations:* Two presentations to academic and stakeholder audiences.

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

**CLIMAS Investigators:** Jeremy Weiss, Michael Crimmins, David DuBois, George Frisvold, Alison Meadow, Marie-Blanche Roudaut

**Research Partners:** University of Arizona—Cooperative Extension; New Mexico State University—Cooperative Extension; Yavapai College—Viticulture and Enology Program

**Additional Support:** NOAA—National Weather Service; NOAA—National Centers for Environmental Information; PRISM Climate group; TopoWx

Orchards and vineyards are particularly sensitive to temperature, and we currently lack information about 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 will work 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. An assessment will be made of 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.



Crop insurance indemnity records will be used to perform a financial assessment of how site and cultivar selection are functioning in the current regional climate. The suitability of present-day orchards and vineyards will be evaluated in the context of anticipated increases in regional temperature.

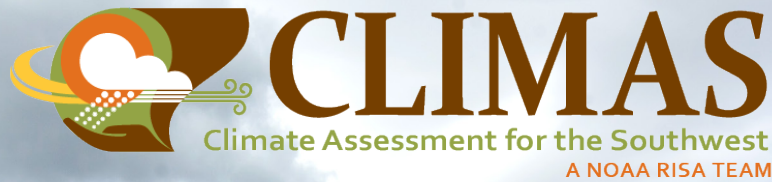
**Deliverables:** 1) *Monthly Climate Viticulture Newsletter*: Based on input from stakeholders, we started a monthly Climate Viticulture Newsletter, in which we provide timely climate information relevant to winegrape growing in Arizona and New Mexico. The first issue was May 2019. 2) *Report*: Weiss J, MB Roudaut. 2018. Initial Assessment of Daily Minimum Temperature from Data Loggers in Routson Orchards. Climate Assessment for the Southwest (CLIMAS), University of Arizona, Tucson. This is a brief comparative analysis of daily minimum temperatures measured at two different locations within a stakeholder orchard in the context of freezing temperatures during late spring. 3) *Conference*: An Exchange on Climate and Viticulture in Yavapai County, Yavapai College Verde Valley Campus, Clarkdale AZ, June 2018; 4) *Presentations*: Nine presentations and exhibits for stakeholder and academic audiences.

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

**CLIMAS Investigators:** Connie Woodhouse, Daniel Ferguson, Andrea Gerlak, Sarah Frederick

The overarching goal of this study is to evaluate the seasonal climatic components that control surface water supplies in the lower Colorado basin, with a specific focus on the influence of temperature on annual streamflow in recent decades. The project is designed to investigate questions and produce scientific results that are meaningful and useful for decision makers in the LCRB. To achieve that goal, the project team will identify interested resource management partners in the LCRB who would like to help in shaping 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 a dialogue 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.

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 role of the monsoon’s contribution to streamflow, and how warming temperatures may affect that contribution.



# The Climate Assessment for the Southwest 2018–2019 Research Highlights and Impacts



## Community Climate Profiles

CLIMAS researchers Alison Meadow, Jeremy Weiss, and Sarah Leroy helped Southwest communities adapt to climate change by producing local climate profiles. These profiles include historical temperature and precipitation data, explanations of regional climate phenomena, current climate trends, and summaries of regional climate change projections and impacts. This year the research team worked with tribal agencies, emergency managers, and a retirement community. One climate profile, made for The Highlands at Dove Mountain community, informed their five-year planning initiative. Adaptation measures in the plan encourage desert-appropriate landscaping, sustainable golf course management practices, and greater awareness of the physical and mental health impacts of climate change on older adults.

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

Negotiations over the Arizona Drought Contingency Plan in 2018 and 2019 were highly contentious. Significant disagreement arose regarding the costs of water cutbacks to Pinal County agriculture and how much water should be reduced. Urban water providers and agricultural representatives relied on George Frisvold's CLIMAS research. His economic impact estimates of agriculture and agribusiness in Pinal County were used in testimony about mitigation funds for Pinal County agriculture. Frisvold also conversed with AZ State Senator Kirsten Engel about potential water conservation requirements in the Arizona Drought Contingency Plan. The plan, approved by the state legislature and signed by the state governor, appropriated \$9 million for groundwater infrastructure projects to mitigate effects of surface water shortages.

## Impacts of Dust Storms on Interstate Travel and Local Trucking Industries

Regional dust storms create dangerous and fatal driving conditions, often reducing visibility to near zero with very little warning. Interstate-10, which connects several major cities across the Southwest, is especially vulnerable as it crosses through a dry lake bed west of Lordsburg, NM. Road closures of even a few hours create economic burdens for trucking companies and for the recipients of the delayed goods and services. David DuBois, working closely with the New Mexico Department of Transportation, National Weather Service Forecast Offices, and trucking companies, characterized and documented the climatic and visual conditions during these storms, using data from interviews, time-lapse camera imagery, and dashboard cameras. This project aims to improve public education about and developing warning systems for dangerous dust storm events. A video produced by the NOAA—RISA program highlights this work: Science Clears the Air in Dust Storm Response <https://youtu.be/ENyIO-coRkg>

For more information, contact Daniel Ferguson, Director, Climate Assessment for the Southwest  
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## What is CLIMAS?

The Climate Assessment for the Southwest (CLIMAS) is a NOAA-funded program that connects researchers at the University of Arizona and New Mexico State University to partners from the private sector, academia, and local, state, federal, and tribal governments. Since 1998, CLIMAS researchers have brought the best available knowledge to weather and climate-related challenges in the Southwest. CLIMAS is funded by the Regional Integrated Sciences and Assessments (RISA) program and the National Integrated Drought Information System (NIDIS), both of which are designed to improve the use of climate information in decision making.

## What does CLIMAS do ?

The CLIMAS team works with regional partners to help social and ecological systems respond to and thrive in a variable and changing climate. The program promotes collaborative research involving scientists, decision makers, resource managers and users, educators, and others who need more and better information about climate and its impacts. Current CLIMAS work falls into six closely related areas: 1) the physical climate of the region; 2) planning for regional water sustainability in the face of persistent drought and warming; 3) the effects of climate on human health; 4) economic trade-offs and opportunities in a warming and drying Southwest; 5) building adaptive capacity within socially vulnerable populations; and 6) regional climate services to support communities as they adapt to climate change.

