Annual Report 2016 2017

Adapting to Climate Variability, Thresholds, and Extremes in the Southwest

CLIMAS
Climate Assessment for the Southwest
A NOAA RISA TEAM

The Climate Assessment for the Southwest

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THE UNIVERSITY OF ARIZONA Institute of the ENVIRONMENT

NOAA RISA Regional Integrated Sciences and Assessments

NM STATE UNIVERSITY

NIDIS


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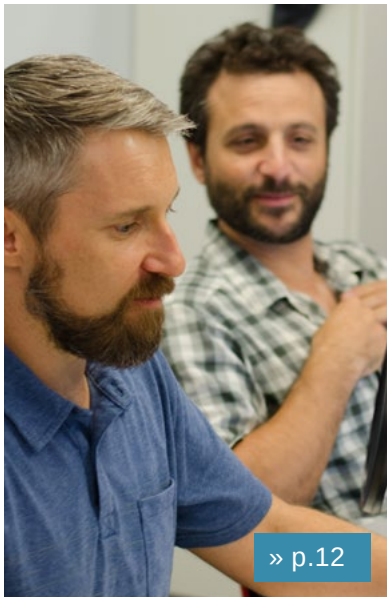
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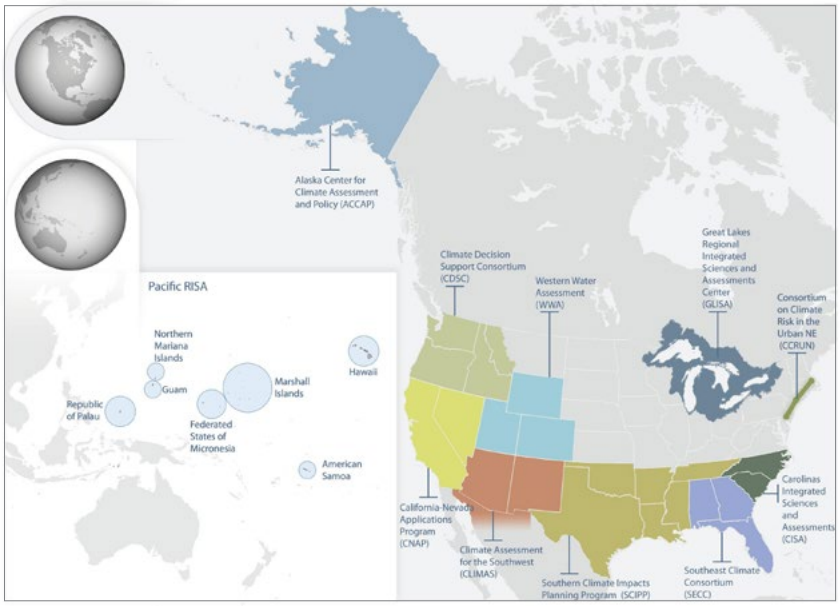
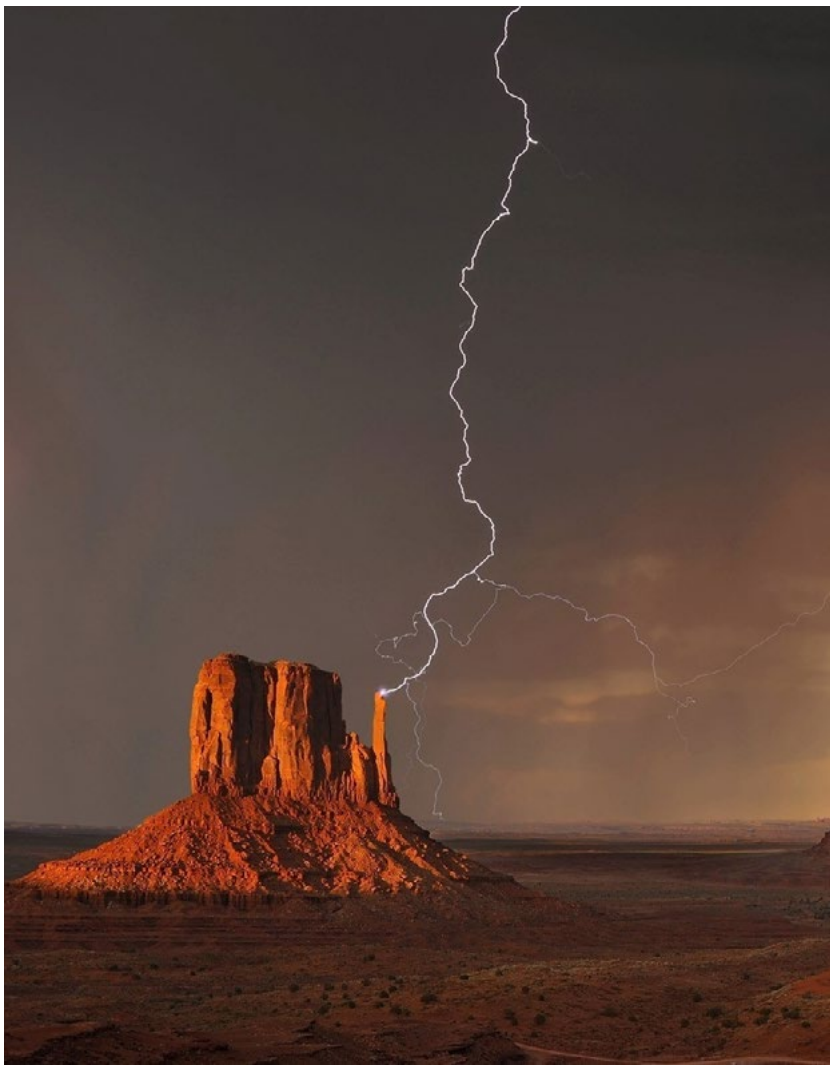


WWW.CPO.NOAA.GOV/CLIMATEPROGRAMS/CLIMATEANDSOCIETALINTERACTIONS/RISAPROGRAM.ASPX

Regionally Integrated Sciences and Assessments (RISA)

In the mid-1990s, the National Oceanic and Atmospheric Administration (NOAA) created the RISA program to support research that addresses complex climate-sensitive issues of concern to decision makers and planners at a regional level. The number of these programs, primarily based at universities, has grown over the last 15 years as the need for climate information in support of decision making has also increased. As of July 2016, 10 RISA teams are funded, covering much of the United States and U.S. territories in the Pacific.



WWW.CLIMAS.ARIZONA.EDU

Climate Assessment for the Southwest (CLIMAS)

CLIMAS is the RISA program in the Southwest. Since its establishment in 1998, CLIMAS has built a large, diverse network of stakeholders and partners who have worked together on a tremendous range of projects. This report highlights the work in which CLIMAS was engaged between June 2016 and May 2017.

The primary focus of the program is Arizona, New Mexico, and northern Mexico, although members of the CLIMAS team conduct research around the world. Headquartered at the University of Arizona's Institute of the Environment, CLIMAS also includes a core group of investigators at New Mexico State University as well as affiliated researchers throughout the West. The CLIMAS mission is to improve the region's ability to respond sufficiently and appropriately to climatic events and changes. The program promotes participatory, iterative research involving scientists, decision makers, resource managers, educators, and others who need more and better information about climate and its impacts.

Building Adaptive Capacity in the Southwest

PHOTO: NAIDU ASHWIN

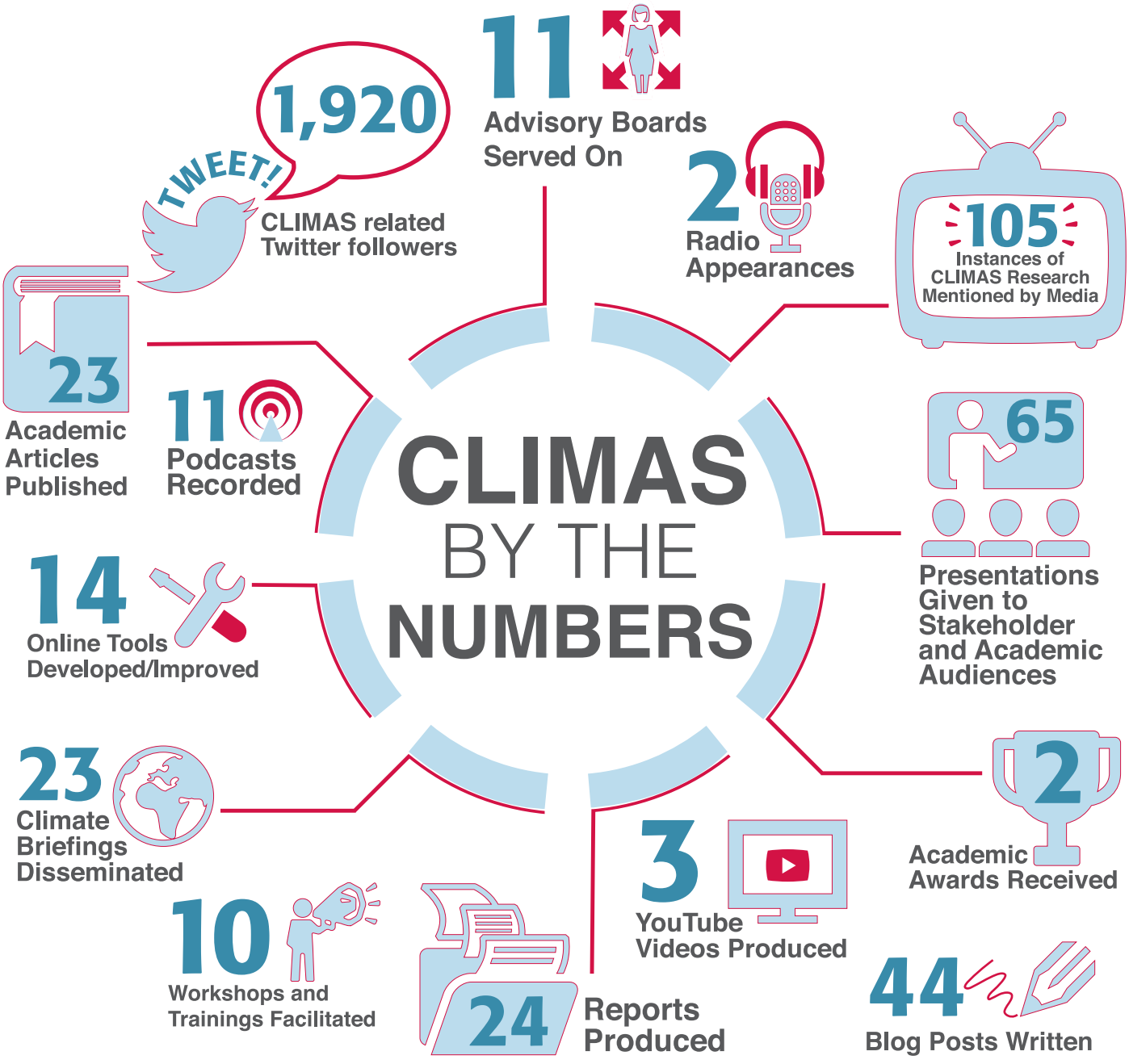
This year, CLIMAS investigators responded to several types of climate service needs to help local and regional decision makers prepare and adapt to climate variability and change. Selected examples include:

- Designing economic guidelines to help shape voluntary, collaborative agreements to share water in the western U.S. **(PAGE 24)**
- Disseminating knowledge to water managers regarding the influence of warm temperatures on regional streamflow reductions. **(PAGE 26)**
- Creating an online tool that allows stakeholders to compare phenological phases of fruit tree and grapevine crops to previous growing seasons. **(PAGE 27)**
- Providing sector-specific information to regional agricultural producers, tailored to melon, grain, and vegetable growers, as well as pasta factories. **(PAGE 29)**
- Delivering city-specific climate information, which was used to implement green infrastructure in a low-income neighborhood. **(PAGE 25)**
- Expanding a prototype outreach model (El Niño Information Hub) to address climate issues that are most important to stakeholders in the Southwest, including drought, monsoon, and health risks. **(PAGE 13)**

2016-2017 Team Highlight

This year, the CLIMAS program re-competed for RISA funding and the CLIMAS team took this effort on collectively. Drawing on our team's expertise and past experience working in the Southwest, we developed an integrated plan to assess social-ecological system buffers to promote regional resilience. The inter- and transdisciplinary projects represented in our proposal emphasize use-inspired research that connects innovative science with the practical needs of decision makers and planners.

One objective in our proposal is to determine the baseline conditions that critical regional social-ecological system buffers were meant to address and how those baselines have changed. Another proposed objective is to assess how regional social-ecological system buffers are currently functioning and how they are likely to perform in the future. The third objective is to evaluate and describe the most effective approaches for supporting Southwest climate resilience efforts with best-available science. This will include expanding existing and building new collaborative partnerships, and working to better understand why and how different groups use drought and other climate information in their decision-making process.



New Areas of Focus and Partnerships

LASCRUCES, NEW MEXICO. PHOTO: DAVID DUBOIS.

CLIMAS Year 5 Assessment – Identifying Emergent Research Priorities and Expanding the Regional Network

CLIMAS Investigators: B. McMahan, L. Keith, G. Owen, A. Maass, and E. Schur

This project aims to better understand the different climate and environmental threats facing urban and rural communities in Arizona and New Mexico. It also investigates the different roles that built environmental systems play in building resilience and reducing vulnerability. This project will: 1) better define how research and practice can contribute to existing concerns; 2) identify plans and gaps linked to drought and climate vulnerability; and 3) expand the CLIMAS network of collaborators and stakeholders. This project will also contribute to the Intermountain West Drought Early Warning System (IM DEWS).

Other Funding: National Integrated Drought Information System (NIDIS)

BRACE AT WORK: CDC'S ROCKY MOUNTAIN SPOTTED FEVER (RMSF) PROJECT IS COMBINING HOMEOWNER EDUCATION, PESTICIDE APPLICATION AND DOG POPULATION CONTROL TO REDUCE TRANSMITTING RMSF TO HUMANS IN A SMALL COMMUNITY OF A TRIBAL RESERVATION IN ARIZONA. PHOTO: CRAIG MANNING/CDC.

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

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

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

This project will identify how academics working on climate and health issues can better serve the stakeholders who are actively working on climate/health adaptation planning. Findings will inform adaptation and mitigation plans for the state of Arizona and help build partnerships throughout the state with CLIMAS and other groups.

Other Funding: Arizona Department of Health Services

Regional Climate Services

PHOTO (CROPPED): DANIEL FERGUSON

Arizona

Southeast Arizona Agricultural Weather and Climate Working Group: Online interactive graphs display time series of cumulative growing degree-days at currently active stations of the Arizona Meteorological Network (AZMET). Time series are updated daily, showing current year values within a context of values from past years. The historical comparison allows stakeholders to estimate how similar or different the timing of phenological phases of fruit tree and vine crops is relative to previous growing seasons. HTTPS://CALS.ARIZONA.EDU/RESEARCH/CLIMATEGEM/PROJECTS/AZMETGDD.HTML

Arizona Business Resilience Initiative – An Initiative To Support Arizona's Business Community In Managing Climate Risk: An urban heat island GIS tool was created that uses Landsat satellite images to identify areas of elevated heat. This tool reflects an electric utility's concern about knowing the explicit location of hot spots in the urban environment, but this process has been expanded into other projects that incorporate urban heat and surface heat anomaly detection.

New Mexico

Air Quality and Climate: A dust storm forecast tool for southern New Mexico was developed to forecast future dust events. The tool uses a recognition algorithm based on regional historical dust storm satellite imagery that is housed in the North American Regional Reanalysis model archive. Sixty dust storm events occurred during 2011–2014. Researchers used these to generate a pattern to compare against non-dust days. Forecasters can use the resulting pattern as guidance for future dust storms.

Southwest Region

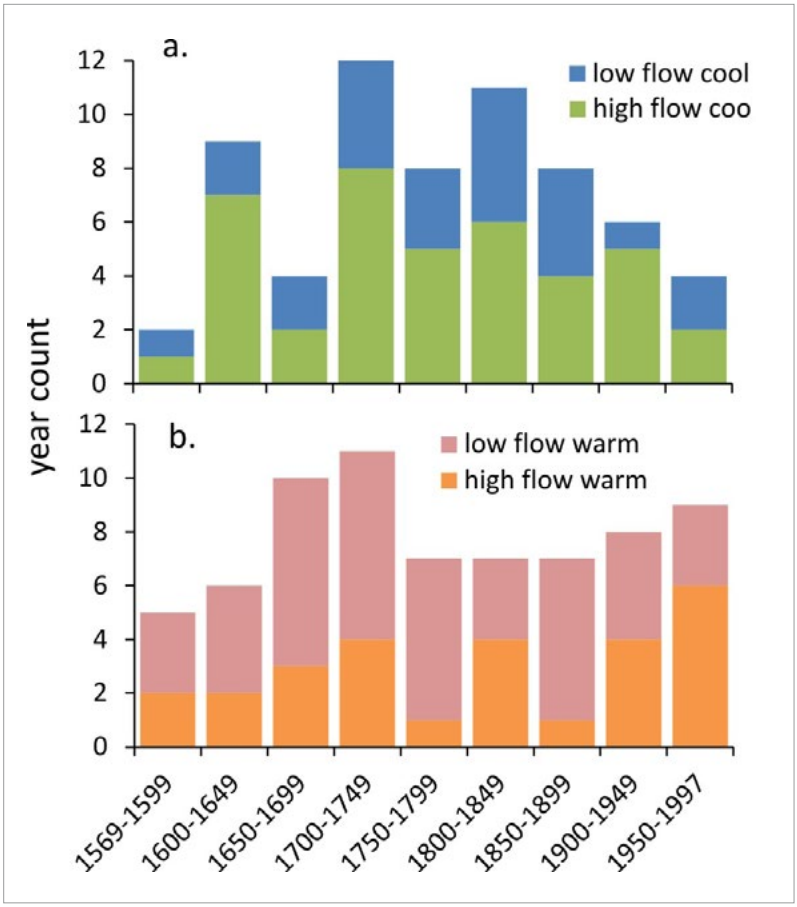
Exploring the Use of Climate and Remote Sensing Data to Support Drought Monitoring Across the Southwest U.S.: DroughtView is a web-based decision-support tool for computers and mobile devices that combines satellite-derived measures of surface greenness with additional geospatial data so that users can visualize and evaluate vegetation dynamics across space and over time. Examples of its recent use include determining rangeland conditions in the context of drought-induced losses for ranchers and related disaster assistance, and improving the placement and timing of vegetation surveys and invasive plant eradication efforts.

For the third consecutive year, organizers of the annual USDA Noninsured Crop Disaster Assistance Program meeting in southeastern Arizona have invited CLIMAS researchers to provide information and data from DroughtView for ranching activities. Land management agencies and University of Arizona Cooperative Extension staff use DroughtView to corroborate their on-the-ground observations with larger, county-level patterns of areas where vegetation growth was low in order to delineate grazing areas where drought-induced losses occurred and determine where disaster assistance was justified. HTTPS://DROUGHTVIEW.ARIZONA.EDU/

Selected Research Findings

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

CLIMAS Investigators: C. Woodhouse and B. Brice



THE NUMBER OF YEARS IN EACH CATEGORY OF COLORADO RIVER FLOW AND INFERRED TEMPERATURE, SHOWN BY HALF-CENTURY PERIODS. A. COOL YEARS, AND B. WARM YEARS.

Temperature has played a key role in conditioning the impacts of some droughts and pluvials on Colorado River flows over past centuries. On a relatively regular basis, persistent droughts contain years with runoff temperatures warm enough to further intensify low flows beyond what would be expected from precipitation deficits alone. Reconstructions of past hydroclimatic variability suggest the proportion of years in which temperature may be a more dominant factor has not changed appreciably over the past four centuries. However, these reconstructions indicate that the ways in which temperatures impact streamflow are shifting. Specifically, warming temperatures may be resulting in less efficient precipitation in terms of its contributions to streamflow.

End users for this information include Colorado River District, Salt River Project, Denver Water, Bureau of Reclamation–Lower Colorado District, and the NOAA Colorado Basin River Forecast Center). More information can be found at **DRIVERS OF DROUGHT IN THE UPPER COLORADO RIVER BASIN.**

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

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

There are five key challenges for extreme heat and public health integrated research in the region: 1) translating climate and health research into evidence-driven interventions and actionable strategies; 2) co-producing discipline-specific environmental and health information to support decisions on all timescales; 3) evolving risk communication strategies to drive behavior changes and inform all populations of the public health risks of extreme heat; 4) enhancing coordination and communication among emergency management entities; and 5) improving public health surveillance and monitoring coupled with improved climate prediction skill at timescales from weeks to inter-annual. End users of this information include the City of El Paso, TX, the City of Las Cruces, NM, Ciudad Juarez, Chihuahua (specifically Protección Civil and the Resilience Office), and NOAA-National Weather Service.

PHOTO: BOB WICK, BLM.

Western Region Climate Services Database Development

CLIMAS Investigators: A. Meadow, B. McMahan, and G. Owen

The Western Region Climate Service Providers Database contains all the public sector and non-profit climate service provider organizations in NOAA's Western Region that were identified by the project team. Researchers identified 137 climate service providers in NOAA's Western Region but found several gaps in service provision: 1) New Mexico and Utah have the least coverage; 2) relatively few providers are focused on human health (16), transportation (10), or economics (10); and 3) tribes are underserved as a stakeholder group, with only 18 providers specifically listing tribes as a key stakeholder.

Municipalities, communities, and other resource managers can use the database when searching for organizations to help provide climate information and support for adaptation decisions. NOAA staff also will use the report and analysis to help prioritize resource management decisions.

HTTP://WRCC.DRI.EDU/CLIMSVCPROVIDERS/

HOOVER DAM

Adaptation Strategies for Water and Energy Sectors in the Southwest

CLIMAS Investigators: B. Colby, G. Frisvold, C. Woodhouse, G. Garfin, S. Deol, and R. Isaacs

Voluntary collaborative agreements to share water and water-supply risks are an effective approach to address the economic damages that can accompany climate-related water supply variability. These innovative water-trading initiatives are being designed and implemented in Colorado and New Mexico. Elected officials and water management agencies have solicited testimony and presentations from project researchers, focusing on implications of water trading in their state.

Economic guidelines for creating and implementing such agreements are being developed through research and stakeholder consultation across the western U.S. Public agencies and non-governmental organizations are developing programs based on an improved understanding of how to collaborate with agricultural participants and how to monitor environmental flow water produced by their programs. These agencies include the U.S. Bureau of Reclamation, U.S. Department of Agriculture, Arizona Department of Water Resources, Central Arizona Project, Salt River Project, New Mexico Office of State Engineer, New Mexico Interstate Stream Commission, the Lower Rio Grande Water Users Association, Tucson Water, and Tucson Electric Power.

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

CLIMAS Investigators: G. Frisvold, T. Bai, and W. Wang

Sprinkler irrigation is a promising climate adaptation in relatively cooler areas and where extreme precipitation events will increase, but less likely in warmer climates and under drier climate change scenarios. For hot, arid parts of the West, other climate adaptation strategies may be more important to pursue.

Growers in Yuma have been able to significantly reduce water use by shifting from long-season crops (cotton, alfalfa) to wheat/vegetable rotations.

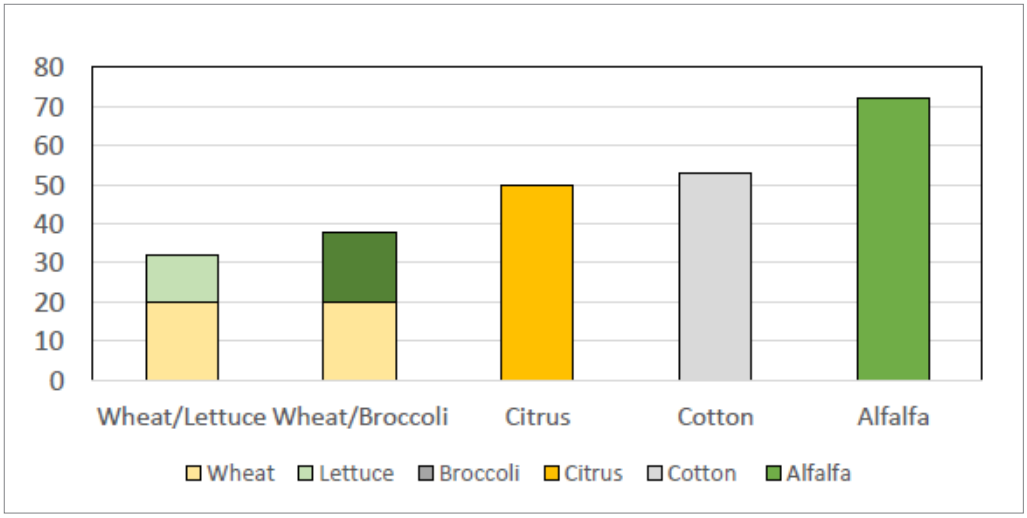


FIGURE 4: ESTIMATED CROP WATER USE IN THE YUMA AREA (INCHES OF CROP EVAPOTRANSPIRATION).

The shift to wheat/vegetable rotations has also dramatically increased water economic productivity (the dollar value of output per acre-foot of water used).

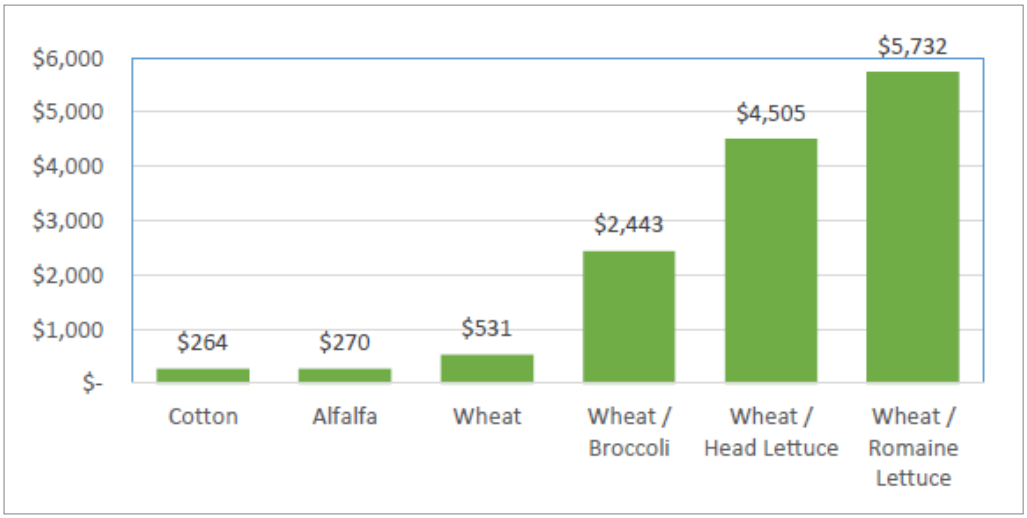


FIGURE 5: WATER ECONOMIC PRODUCTIVITY: GROSS REVENUE PER ACRE-FOOT WATER CONSUMED.

These results are useful to agricultural producers, including the Yuma County Water Users' Association, Arizona Small Grains Research and Promotion Council, Yuma Center for Excellence in Desert Agriculture, Greater Yuma Development Corporation, Arizona Cotton Growers Association, and the USDA Office of the Chief Economist: World Agricultural Outlook Board.

Outreach Activities

PHOTO: ZACK GUIDO.

The Southwest Climate Outlook

CLIMAS Investigators: B.McMahan, G. Garfin, M. Crimmins, D. DuBois, and E. Huddleston

The Southwest Climate Outlook (SWCO) summarizes climate and weather information from disparate sources in nonscientific language, providing more than 1,600 people with timely climate-related information. Since *SWCO*'s inception in 2002, the publication has evolved into a tool for two-way communication with stakeholders and a platform for responding to needs throughout the region. *SWCO* continues to be a primary way in which CLIMAS interacts with a larger audience of stakeholders and the general public.

Feedback on *SWCO* is positive. For example, one reader wrote, "I have used CLIMAS products since I began working with at the Bureau of Reclamation in 2006. I have always found the *Southwest Climate Outlook* to be extremely informative, and a useful tool to communicating climate issues in the Southwest with our stakeholders. The graphics and information are always timely, and I've used the graphics in frequent presentations. Now that I work for the Colorado Basin River Forecast Center, I still find the *Outlook* extremely useful for the same reasons above. CLIMAS is just a great resource for distilling global and national products to services that impact the Southwest."

Other Funding: NIDIS – Coping with Drought

MICHAEL CRIMMINS (FOREGROUND), AND ZACK GUIDO.
PHOTO: DANIEL FERGUSON.

Southwest Climate Podcasts

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

El Niño, the monsoon, increasing temperatures, and dwindling reservoir storage are just a few of the climate-related issues that periodically punctuate the news cycle in the Southwest. CLIMAS scientists discuss these issues in monthly climate podcasts that synthesize information from disparate sources and translates national and global discussions into what they mean for the Southwest. Podcasts received between 100 and 300 visits to the page. Listeners who syndicate the downloads via a podcast app or iTunes are not reflected in these numbers. The podcasts are publicized every month on social media. They garner the most traffic when another media outlet picks up the content, promotes it, or endorses it to their network.

There remains an active and enthusiastic audience for these podcasts. One listener wrote, "I found CLIMAS a few years back. I subscribed to both the podcast and the Outlook. I was immediately hooked. The podcasts are the perfect example of great science that reaches out from within the academic community to support and inform the local community in a most meaningful way."

HTTP://WWW.CLIMAS.ARIZONA.EDU/MEDIA/PODCASTS

Other Funding: NIDIS – Coping with Drought

HURRICANE PATRICIA, PART OF A BUSY 2015 HURRICANE SEASON IN THE NORTH PACIFIC DRIVEN PARTLY BY WARM EL NIÑO WATERS. PHOTO: NASA'S EARTH OBSERVATORY.

Southwestern Climate Information Hubs

CLIMAS Investigators: B. McMahan, M. Crimmins, H. Brown, E. Huddleston, G. Owen, J. Weiss, and G. Garfin

As the El Niño event wound down, the El Niño Hub was updated to become the El Niño Southern Oscillation Hub to capture La Niña outlooks and activity. This pilot process was adapted to help us update our Southwestern Climate section of the website. We used this information hub model as a template for other topical areas of interest, such as drought, monsoon, temperature, and precipitation. We also have identified other emergent areas in which these types of hubs would be useful, such as health and environmental risk.

The general public and media contacts were receptive to aggregated information that was focused on timely outreach and in anticipation of an event.

Other Funding: NIDIS – Coping with Drought

PHOTO: DANIEL FERGUSON.

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

CLIMAS Investigators: B. McMahan, M. Crimmins, G. Garfin, D. Ferguson, G. Frisvold, H. Brown, and G. Owen

Southwestern Oscillations is an ongoing source of engagement with the general public and other scientists/practitioners. It is the hub for news, information, and commentary about CLIMAS research and climate-related issues. This blog is updated regularly to distribute news, updates, and other information on CLIMAS research projects and publications.

HTTP://WWW.CLIMAS.ARIZONA.EDU/BLOG

LAKE TRAVIS. TEXAS DROUGHT. PHOTO: AUSTIN WATER.

The Rio Grande-Bravo Outlook

CLIMAS Investigators: G. Garfin and S. Leroy

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

HTTP://WWW.CLIMAS.ARIZONA.EDU/RGBO

Key Publications

Udall, B. and J. Overpeck. 2017. The twenty-first century Colorado River hot drought and implications for the future. *Water Resources Research* 53(3):2404-2418. **DOI: 10.1002/2016WR019638**

- Between 2000 and 2014, annual Colorado River flows averaged 19 percent below the 1906–1999 average, the worst 15-year drought on record. Approximately one-third of the flow loss is due to high temperatures now common in the basin, a result of human caused climate change. Previous comparable droughts were caused by a lack of precipitation, not high temperatures. These results suggest that future climate change impacts on the Colorado River will be greater than currently assumed.

Crimmins, M., D. Ferguson, A. Meadow, and J. Weiss. 2017. Discerning "flavors" of drought using climate extremes indices. *Journal of Applied Meteorology and Climatology* 56:989–1001. **DOI:10.1175/JAMC-D-16-0270.1**.

- In a case study focused on the Four Corners region of the southwestern U.S., the authors found that the driest four-year intervals, characterized by similar annual and interval total precipitation anomalies, represent dramatically different "flavors" of drought. Results indicate that operational drought monitoring and historical drought assessments in arid and semiarid regions would benefit from daily-based hydroclimatic extremes indices, especially in light of expected climate change-driven changes to the hydrologic cycle.

Frisvold, G. 2016. Trends and patterns of water use in U.S. cotton production. *Proceedings of the Beltwide Cotton Conferences*. Memphis, TN: National Cotton Council. **HTTPS://CALS.ARIZONA.EDU/AREC/SITES/CALS.ARIZONA.EDU.AREC/FILES/PUBLICATIONS/%282016%29%20TRENDS%20AND%20PATTERNS%20OF%20WATER%20USE%20IN%20US%20COTTON%20PRODUCTION.PDF**

- This study compared water use and productivity in cotton production in western U.S. states and the U.S. in general across 30 years, based on data from USDA's Farm and Ranch Irrigation Survey. From 1984 to 2013, water applications to cotton in California, Arizona, and New Mexico fell by more than 3.9 million acre-feet (MAF). This 71-percent reduction in water use is equivalent to 68 percent of total residential water use in the region.

Meadow, A. and D. Ferguson. 2017. Our climate is doing what? Tailoring information about regional climate to support local adaptation decision making. *Rural Connections*. Spring 2017. **HTTP://WRDC.USU.EDU/FILES-OU/PUBLICATIONS/OUR-CLIMATE-MEADOW-RCSPR2017.PDF**

- Tailored data and information about local climate is a necessary early step to adaptation planning. Because most communities do not have climate experts on staff, the authors have developed a process to provide locally relevant climate data and information to support these efforts. This process involves the creation of Community Climate Profiles, which summarize historic and recent climatic conditions, as well as information about climate change, focused on a particular area.

Weiss, J. and M. Crimmins. 2016. Better coverage of Arizona's weather and climate: Gridded datasets of daily surface meteorological variables. *Arizona Cooperative Extension Publication* AZ1704. University of Arizona, Tucson, AZ. **HTTPS://EXTENSION.ARIZONA.EDU/PUBS/AZ1704-2016.PDF**

- Weather stations are sparsely and irregularly located throughout Arizona. Information recorded at these sites may not represent meteorological conditions at distant, non-instrumented locations or over broad areas. This bulletin reviews the current suite of daily weather datasets, including where and how to access them, as well as the general suitability of these datasets for different uses.

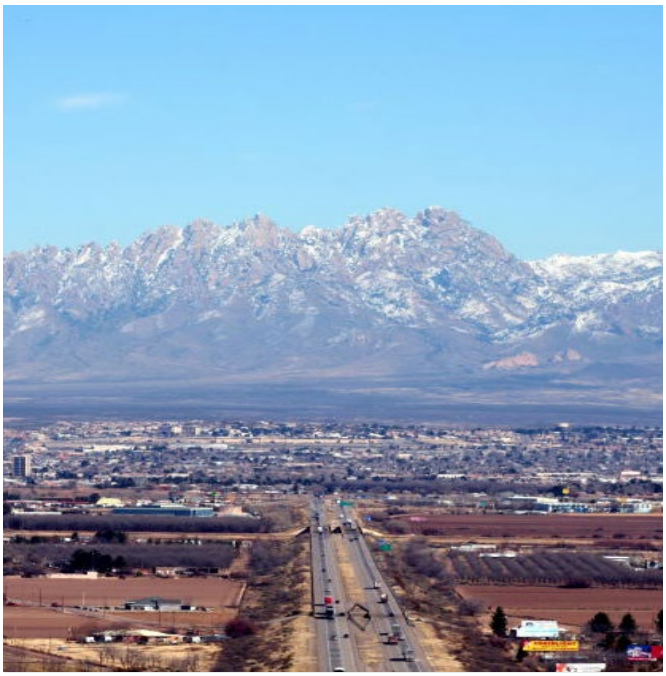
Kerna, A., B. Colby, and F. Zamora. 2017. Cultural and recreational values for environmental flows in Mexico's Colorado River Delta. *Water, Economics, and Policy* 03: 1650035. **HTTP://DX.DOI.ORG/10.1142/S2382624X16500351**

- Worldwide, aquatic ecosystems subsist on water leftover from agricultural, industrial, and municipal water uses. While binational agreements have temporarily provided water for the Colorado River Delta in Mexico, dedication of water to support aquatic ecosystems is rare. Results from this study indicate strong support for Delta restoration, including positive willingness to pay for an assured source of water to sustain the Delta's ecosystem and the recreational opportunities it provides.

González-Delgado, A., M. Shukla, D. DuBois, J. Flores-Márgez, J. Hernández Escamilla, and E. Olivas. 2017. Microbial and size characterization of airborne particulate matter collected on sticky tapes along the U.S.-Mexico border. *Journal of Environmental Sciences* 53:207-216. **HTTP://DX.DOI.ORG/10.1016/J.JES.2015.10.037**

- This paper addressed possible causes for degraded respiratory health during dust storms. The study compares fungal varieties in air samples near agricultural activities against air samples from urban areas. Samples were collected in Ciudad Juarez, Mexico, and Luna and Dona Ana counties in New Mexico. Alternaria, Penicillium, and Fusarium were frequently found fungi in the U.S. sites while Alternaria and Aspergillus were commonly observed in the Mexican sites.

Selected Applications of CLIMAS Work



THE CITY OF LAS CRUCES, WITH THE ORGAN MOUNTAINS IN THE BACKGROUND.

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

CLIMAS Investigators: G. Garfin and S. Leroy

Researchers delivered a report regarding the climate of Las Cruces, NM, providing a concise summary of the climate and extreme weather events that affect the city. This information has informed planning and preparedness for extreme weather events now and in the future. For example, the City of Las Cruces implemented rainwater harvesting cisterns at a juvenile citation center and developed a green infrastructure plan for stormwater management in a low income, high risk neighborhood. Leveraging these project results, the city also garnered a grant ($400,000) to implement further projects in this neighborhood.

SIPHON TUBES USED FOR FURROW IRRIGATION ON ROMAINE LETTUCE. YUMA, AZ.. PHOTO: JEFF VANUGA, USDA NATURAL RESOURCES CONSERVATION SERVICE.

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

CLIMAS Investigators: G. Frisvold, T. Bai, and W. Wang

Arizona growers directly asked for analysis on the contribution of Arizona's vegetables, melons, and small grains to the state economy. The total of the state's vegetable and melon industry cluster was more than $2.5 billion in sales in 2015. Arizona vegetable and melon production requires more than 26 million hours of on-farm labor. The total contribution of small grains production to Arizona's economy in 2015 was $300 million in sales. Farms specializing in vegetable and melon production accounted for 29 percent of Arizona grain sales. The Arizona Department of Agriculture and the Arizona Farm Bureau have contacted CLIMAS investigators for additional information. Results have been published in industry newsletters:

HTTPS://CALS.ARIZONA.EDU/AREC/PUBLICATION/CONTRIBUTION-ARIZONA%E2%80%99S-VEGETABLE-AND-MELON-INDUSTRY-CLUSTER-STATE-ECONOMY

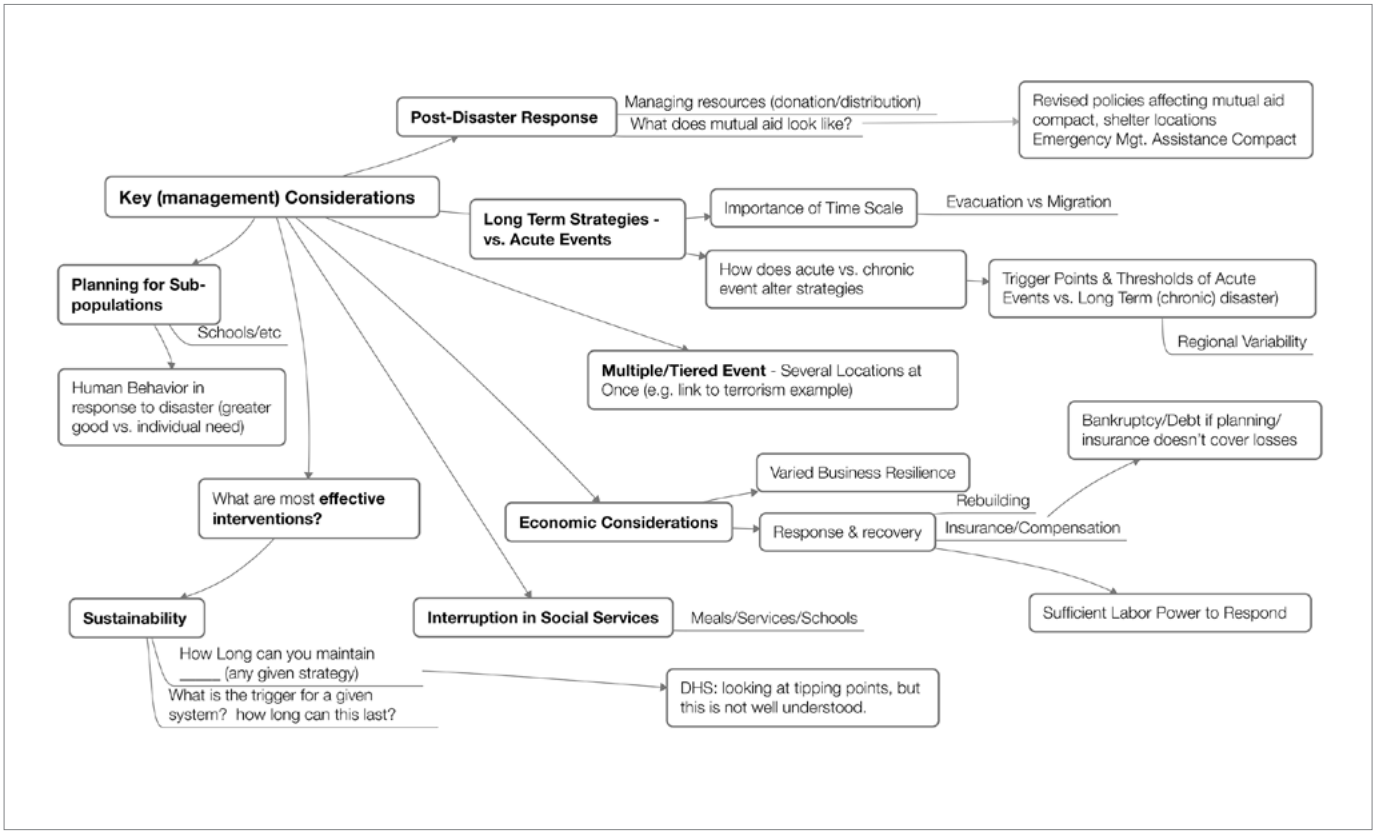
HTTPS://CALS.ARIZONA.EDU/AREC/PUBLICATION/CONTRIBUTION-SMALL-GRAINS-PRODUCTION-ARIZONA%E2%80%98S-ECONOMY

Preparing for High-Consequence, Low-Probability Events: Heat, Water & Energy in the Southwest

Lead CLIMAS Investigator: S. Leroy, G. Garfin, and B. McMahan

A risk cascade map produced in conjunction with this project was used in a National Research Council (NRC) report, based on testimony given to the NRC regarding risk management for climate assessments. Citation: National Research Council, 2016. *Characterizing Risk in Climate Change Assessments: Proceedings of a Workshop*. Washington, DC: National Academies Press.

DOI: HTTPS://DOI.ORG/10.17226/23569



Air Quality and Climate

CLIMAS Investigators: D. DuBois, R. Armenta, Y. Zhao, A. Arredondo, and Z. Ghodsizadeh

Results from this project have strengthened the partnership between the New Mexico Department of Transportation (DOT), the New Mexico Climate Center, and the National Weather Service forecast offices in Albuquerque and Santa Teresa on dust storm forecasting. The NM DOT office has obtained additional funding to continue this collaboration and to address dust control at two locations in southwestern New Mexico as a result of the increased interest in dust storms.

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

CLIMAS Investigators: G. Garfin and S. Leroy

The mayors of the cities of Ciudad Juarez, Chihuahua, El Paso, TX, and Las Cruces, NM, declared May 2017 to be "Heat Awareness Month." The resilience and sustainability staff in each city convened events and outreach related to this declaration. This project also catalyzed new activities and new partnerships between climate scientists, public health practitioners, and urban planners, leading to exciting prospects for ongoing research, stakeholder partnerships, and social learning.

Program Impact – Evaluation Efforts

The intellectual basis for our current program evaluation is theory-based evaluation, which uses a series of Action Logic Models to help assess the outputs, outcomes, and broader impacts within four elements of our work.

PHOTO CREDIT: DANIEL FERGUSON.

Examples of metrics we are collecting for the program evaluation include:

Outreach: interactions with media; online contributions produced by CLIMAS team members; presentations; and social media presence.

Graduate and Undergraduate Training: Breadth and depth of student interactions with CLIMAS through the Connecting Environmental Science and Decision making (CESD) program, the Climate & Society Fellowship, and employment as graduate research assistants.

Advancing Knowledge: Publications and citations in other academic research, and documenting stakeholder applications of publications.

Use-Inspired Science and Decision Support: Focus on outputs, and short- and medium-term outcomes. Data collection and metrics are co-designed with CLIMAS PIs. Metrics are gathered from interviews with key stakeholders for each project.

Emerging Results:

We are currently analyzing data regarding our program-level impact. This long-term data collection will allow us to understand broader program impact from 2012 to 2017.

- One emerging result emphasizes the importance of social aspects in climate adaptation and climate services, such as increasing social capital and social cohesion in a community, and expanding social and information networks on all different geographic scales. Building long-term relationships with regional partners is one positive value.
- Climate information and outreach serves as a way to open discussion about the different ways people experience scientific representations of climate.
- There is value in understanding the complex process of decision making regarding climate in different contexts. There are multiple ways of measuring the value of a product or project, beyond traditional economic measures. Adapting to climate variability and change is a never-ending process of collaboration, co-learning, critiquing the results, and moving forward with something new.

Education and Training

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

CLIMAS Investigators: C. Woodhouse and D. Ferguson

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

The seminar is currently being translated to an online professional development version, supported by the Provost and Vice Provost for Digital Learning and Student Engagement at the University of Arizona.

Other funding: School of Geography and Development, The University of Arizona

CLIMAS FELLOW DANIELLE JOHNSON.

2016 Climate & Society Fellows

The Climate & Society Graduate Fellows Program provides support for University of Arizona graduate students whose work is focused on the nexus of climate research and decision making. While CLIMAS generally conducts research in the southwestern U.S., this fellowship, funded by the UA Office of Research and Discovery, is open to students conducting research anywhere in the world.

The 2016 fellows received funding in January and finished their projects in December. Selected results of their fellowships are included below:

(RIGHT) CLIMAS FELLOW SALEH AHMED.

Climate Services for Improved Adaptation Decisions: Focus on Coastal Bangladesh

CLIMAS Fellow: Saleh Ahmed

The overarching goal in Bangladesh should be to integrate use-inspired and stakeholder-driven climate services so that local farmers and other community members can use available climate information to improve their adaptation decisions. Strengthening the national capacity for weather and climate services in Bangladesh has tremendous implications for nations' interests for climate resilience and adaptation. Several projects have aimed to strengthen the capacity of the government of Bangladesh to deliver weather and climate information in priority sectors and to prepare for climate variability and hydro-meteorological disasters. However, a very limited number of them address the production and delivery cycle of climate information, ranging from producers of science to the end users.

PHOTO: CLIMAS FELLOW JOY LIU.

The Local Development of Collaborative Governance under the Sloping Land Conversion Program in Rural, Arid China

CLIMAS Fellow: Joy Liu

This project documents top-down, bottom-up, and mixed approaches towards climate and drought adaptation in rural China, investigating knowledge exchange mechanisms between governments, local communities, and non-governmental organizations. The project traces the initial implementation and execution of the Sloping Land Conversion Program (SLCP) in Shilou County, Shanxi Province, China, since 1999 and seeks to understand the role of NGOs in natural resource governance in rural China. Key findings include: 1) a top-down approach to environmental governance decreases the level of knowledge exchange and the space for 'open' discussion between participants and reduces opportunities for long-term capacity building for the most vulnerable participants—farmers; and 2) implementing environmental policies and programs demands that local officials understand the scientific knowledge embedded within these programs, but local officials may or may not have sufficient scientific training to do so.

Solar Program Report: A Restorative Economy Program Case Study

CLIMAS Fellow: Stina Janssen

PEABODY COAL COMPANY IN BLACK MESA AREA OF NORTHEASTERN ARIZONA. PHOTO CREDIT: U.S. NATIONAL ARCHIVES AND RECORDS ADMINISTRATION (NARA).

Black Mesa, home to the largest coal deposit in the U.S. and adjacent to five coal-fired power plants, has been strip-mined for coal since the 1960s. While distant executives reap the profits, 18,000 Navajo households are off-grid, without access to electricity. The Restorative Economy Program developed by the Black Mesa Water Coalition provides alternatives to the coal-based economy. Recommendations for solar on the Navajo Nation include:

1. Net-metering - Without a net-metering policy that pays grid-tied producers for the power they generate, solar users are unable to sell excess power back to the grid. A net-metering policy would facilitate the sourcing of more clean energy for use by Navajo Nation residents.
2. Investment in affordable solar - Lack of availability and access to capital is one of the greatest barriers for scaling solar to meet the need present on the Navajo Nation. The Navajo Nation and federal government should invest further in solar for off-grid residential and community use. However, private investment is also critical.
3. Green jobs and green business incubator - While the solar industry has one of the fastest-growing rates of job creation, not enough of these job opportunities are accessible to Native workers. A solar program on the Navajo Nation must include opportunities for training and jobs creation and provide opportunities for business management education to enable Native workers to start, own, and manage solar companies.

CLIMAS FELLOW SCHUYLER CHEW.

Collaborative Outreach and Climate Adaptation Planning with the Pyramid Lake Paiute Tribe

CLIMAS Fellow: Schuyler Chew

The Pyramid Lake Paiute Tribe (PLPT) in Nevada is deeply connected physically, culturally, and spiritually to Pyramid Lake and has made substantial gains to protect this ecosystem. Through collaborative efforts, a research team has been working with PLPT to understand how climate change might impact tribal water resources. We developed a mass-balance approximation tool to simulate Pyramid Lake elevation over time under various climate change scenarios and proposed 10 adaptation recommendations that might enhance tribal adaptive capacity. This project built on this research endeavor by discussing with PLPT decision makers how to improve the mass-balance tool's usefulness for water resource planning.

BUENO RIVER (RÍO BUENO). PHOTO: JASON HOLLINGER.

Outreach for Small Hydropower Governance in Chile

CLIMAS Fellow: Sarah Kelly-Richards

Globally, renewable energy production is promoted as a mitigation strategy for climate change. This project supported social justice and environmental sustainability within the transition to renewable energy. After spending time with communities learning about the issues they view as most important, the project focus shifted to studying how: 1) the indigenous consultation process works for hydropower development; 2) changes in water availability (quantity and quality) affect traditional water uses and rural livelihoods; and 3) co-producing basic territorial information with local stakeholders can inform local and regional decision-making processes.

With local stakeholders in the Bueno river basin, we developed maps to understand territorial change. For a broader public, we created handouts on issues such as how the environmental impact assessment process works. Recurrent dialogues with indigenous leaders and government officials guided the investigation, allowing more nuanced research questions and shared understanding. This ongoing exchange led to policy recommendations on the environmental, regulatory, and indigenous rights issues associated with small hydropower development.

2017 Fellows

Fellows selected for 2017 are engaged in a number of activities: working with women in collective farming initiatives and climate change adaptation in Kerala, India; partnering with the Navajo Nation Department of Water Resources to enhance understanding of surface water resources in the Chuska Mountains; and investigating how people's climate-related vulnerabilities, risks, and opportunities interface with regional inequality and marginalization in the Kaipara Catchment in New Zealand.

LEFT: SHIPROCK & THE CHUSKA MOUNTAINS. PHOTO: USGS. CENTER: PORT ALBERT WHARF, KAIPARA HARBOUR, NEW ZEALAND. PHOTO: BRIAN SCANTLEBURY. RIGHT: AN INDIAN MERCHANT DISPLAYS HER PILE OF GREEN CHICKPEAS. PHOTO: JORGE ROYAN.

CLIMAS Contributions to the NIDIS Regional Drought Early Warning System 2016-2017

THE FOREST SERVICE PILE LIMBS AND DEBRIS FOR FUTURE PRESCRIBED BURNING. PHOTO: RAYMUNDO VALENCIA, USDA.

Several CLIMAS projects contributed to developing capabilities and methodologies to advance drought early warning systems in the Southwest U.S. Project titles are categorized below. Further details about project contributions can be found in the descriptions beginning on page 24.

Convene and collaborate with regional stakeholders

- Southeast Arizona Agricultural Weather and Climate Working Group
- CLIMAS Year 5 Assessment – Identifying Emergent Research Priorities and Expanding the Regional Network

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

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

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

- Air Quality and Climate
- Exploring the use of climate and remote sensing data to support drought monitoring across the Southwest U.S.

Improve the usefulness of drought indicators and prediction products for drought preparedness

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

Deliver products and services at regional and local levels

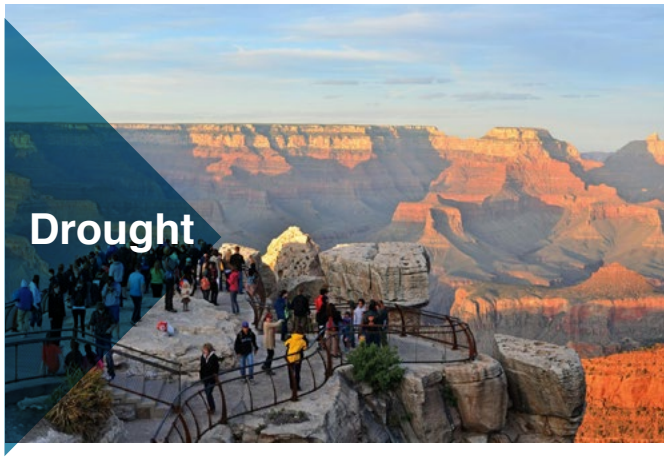
- *The Southwest Climate Outlook*
- Southwest Climate Podcasts

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

- Adaptation to Climate Variability and Change: Markets, Policy, Technology, and Information
- Adaptation Strategies for Water and Energy Sectors in the Southwest
- CLIMAS Heat Extremes Assessment (HEAT) – Exploring the Cascading Effects of Climate Extremes in the Southwest
- Sectoral Impacts of Drought and Climate Change
- Using Critical Thresholds to Customize Climate Projections of Extreme Events to User Needs and Support Decisions

CLIMAS Projects: Areas of Focus

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



Adaptation & Vulnerability

Adaptation Strategies for Water and Energy Sectors in the Southwest

CLIMAS Investigators: B. Colby, G. Frisvold, C. Woodhouse, G. Garfin, S. Deol, and R. Isaacs

THE UPPER RIO GRANDE NEAR CREEDE, COLORADO. PHOTO: JERRY R. DEVAUL

Abstract: 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, as well as guidelines for using these tools, to enhance supply reliability.

Findings: Voluntary collaborative agreements to share water and water-supply risks are an effective approach to address the economic damages that can accompany climate-related water supply variability. Economic guidelines for creating and implementing such agreements are being developed through research and stakeholder consultation in various areas of the western U.S.

Selected Deliverables: Five publications regarding water demand, water trading, water for ecosystem services, and drought.

Eight presentations to stakeholders in water management, agriculture, and policy fields.

Colby served on eight advisory committees for government agencies and non-governmental organizations.

Other Funding: NOAA Regional Climate Centers (RCC); NOAA Sectoral Applications Research Program (SARP); U.S. Bureau of Reclamation; Walton Family Foundation; and The Sonoran Institute

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

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

PHOTO: JULIE JACOBSON/AP/CORBIS.

Abstract: Climate extremes pose serious threats to human health, place increasing demands on municipal services and infrastructure, and threaten the long-term sustainability of a region. In the Southwest, heat presents a unique opportunity to study the intersection between an acute event (e.g., a multi-day heat wave) and underlying vulnerabilities and risks. It also presents an opportunity to look for cross-sector impacts and potential cascades of impacts.

Findings: Project analysis and framework has helped inform ongoing CLIMAS vulnerability assessment frameworks by highlighting the intersection of acute impacts with long-term patterns of climate and environmental vulnerability.

Other funding: NIDIS – Coping with Drought

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

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

Abstract: The project was designed to assist regional urban network managers of the Western Adaptation Alliance (WAA) in communicating with key constituencies in their communities to broaden support for action on climate adaptation and improve preparedness. Specifically, this involved: a) inventorying major extreme events of five key climate impacts for each WAA city and across the region; b) recording specific actions taken following those events; c) developing narratives for each class of impact; and d) creating a toolkit for the highest priority impact—extreme heat events.

Selected Deliverables: ESRI Story Maps: Narratives of each of the climate extremes in the region since 1960. Each story map highlights specific examples of extreme events in various cities and their impacts and examples of how cities are preparing for these types of extremes. Stakeholders continued to make new story maps for 2016–2017.

Other funding: City of Las Vegas/Urban Sustainability Directors Network; NIDIS – Coping with Drought

Evaluating Climate Change Adaptation in Tucson, AZ

CLIMAS Investigator: G. Owen

TUCSON, AZ. PHOTO: DANIEL FERGUSON.

Abstract: This research addresses the gaps between adaptation theory, planning, and practice by reviewing case studies of adaptation success around the world. The project critically analyzes documentation of success in adaptation projects. This information informs continuing debates on the science of science policy, adaptation funding, and evaluation.

Findings: Emerging results suggest that the most successful components of adaptation actions occurring across the world fall into the categories of farming technology, social cohesion, or incorporating local contexts and voices.

Other funding: School of Geography and Development, The University of Arizona

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

CLIMAS Investigators: G. Garfin and S. LeRoy

Abstract: Many communities already are vulnerable to extreme events, and many of these vulnerabilities will increase with climate change. Identifying and better understanding critical thresholds for extreme events is key to developing effective community responses to climate change. In this project, researchers tested a methodology for using a participatory process to define critical thresholds for extreme events and for using these thresholds to customize climate projections to community--specific needs.

Findings: The thresholds concept is useful as an entry point for discussions about climate change. It helps ground conversations in issues of concern to local decision makers and puts projected climate changes in the context of the historical baseline of extreme events. Nevertheless, most participants were either not prepared, or not motivated, to think beyond the daily to weekly timescales. Adaptation in these communities, and likely many others, is opportunistic but still has value and can help build resilience.

Selected Deliverables: Two reports: One documents the process and results of the project, and the other provides a summary of the climate and extreme weather events that affect the City of Las Cruces, NM.

Other Funding: NOAA Sectoral Applications Research Program (SARP); NIDIS – Coping with Drought

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

CLIMAS Investigators: C. Woodhouse and B. Brice

LAKE POWELL, AZ.

Abstract: The purpose of this project is to investigate Colorado River basin droughts and the climatic factors that influence them. The project uses paleoclimatic data to extend instrumental climate and flow records, along with climate change projections, to assess the range of possible conditions that may be expected to occur and determine how warming temperatures may influence river flow and water supply in the future.

Findings: Temperatures have a key role in years when annual flows are more or less than expected, given cool season precipitation. The years in which warm temperatures reduce streamflow efficiency with regard to precipitation have been increasing since the mid-1980s. Paleoclimatic analyses suggest this could be due to the impact of climate change on the upper Colorado River basin. Climate change scenario analyses pointed to the importance of antecedent conditions and suggest a variety of future flow conditions could result from the same changes in climate.

Selected Deliverables: A project website was maintained, containing presentations, publications, and the final report:
DRIVERS OF DROUGHT IN THE UPPER COLORADO RIVER BASIN

A fact sheet summarizing results from this project was distributed to water managers and other interested stakeholders.
HTTPS://PRD-WRET.S3-US-WEST-2.AMAZONAWS.COM/ASSETS/PALLADIUM/PRODUCTION/S3FS-PUBLIC/ATOMS/FILES/UCRBSTUDYFACTSHEET.PDF

Other Funding: Department of the Interior Climate Science Centers

RISA: An Organizational Ethnography

CLIMAS Investigators: A. Meadow

Abstract: The RISA program was founded in 1995 as an experiment in the delivery of climate information to decision makers. In this project, the researchers are applying organizational ethnographic methods to develop a comprehensive history of the program and a description of its structure and function. This 20-year anniversary of the RISA is an excellent time to reflect upon how the program was developed and how it might help other boundary and climate service organizations structure their programs to optimize climate service delivery, collaborative knowledge development, and learning within the organizations.

Findings: The RISA network has been guided by the overarching goal of developing science in such a way as to have beneficial, real-world impact. The network has used five general strategies to achieve this goal: 1) creating transdisciplinary spaces; 2) using climate variability as a way to connect with end-users, then introducing climate change concepts once relationships and science were strong enough; 3) maintaining a focus on regional-scale science and decisions; 4) maintaining a focus on learning within the organization/network; and 5) using innovative approaches to program management to keep the network functioning.

Other Funding: NOAA Climate Program Office

Decision Support

Southeast Arizona Agricultural Weather and Climate Working Group

CLIMAS Investigators: M. Crimmins and J. Weiss

HANDLINE SPRINKER IRRIGATION GERMINATING CROPS IN YUMA, AZ.. PHOTO: JEFF VANUGA, USDA

Abstract: University of Arizona Cooperative Extension and the National Weather Service (NWS)-Tucson have developed a working group focused on engaging the agricultural community of southeast Arizona. The working group is focused on assessing information needs, providing training opportunities and technical support, conducting applied research, and developing new and enhanced decision-support tools. Main activities have included several training and needs assessment workshops, developing and maintaining a listserv with more than 100 subscribers, and developing new NWS forecast information visualizations and interfaces focused on frost and freezing events.

Selected Deliverables: Online interactive graphs display time series of cumulative growing degree-days at currently active stations of the Arizona Meteorological Network (AZMET). Time series are updated daily, showing current year values within a context of values from past years. The historical comparison allows stakeholders to estimate how similar or different the timing of phenological phases of fruit tree and vine crops is relative to previous growing seasons.

HTTPS://CALS.ARIZONA.EDU/RESEARCH/CLIMATEGEM/PROJECTS/AZMETGDD.HTML

Other Funding: USDA-Regional Climate Hub; USDA-Agricultural Resource Services; U.S. Geological Survey; NIDIS – Coping with Drought; NOAA National Weather Service; University of Arizona Cooperative Extension

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

CLIMAS Investigators: M. Crimmins and J. Weiss

Abstract: DroughtView combines geovisualization tools with remote sensing products to detect drought conditions. The DroughtView tool served as a key piece of information to help the National Resources Conservation Service, U.S. Bureau of Land Management, and U.S. Forest Service range managers determine drought conditions and Farm Services Agency drought disaster assistance eligibility.

Selected Deliverables: DroughtView is a web-based decision-support tool for computers and mobile devices that combines satellite-derived measures of surface greenness with additional geospatial data so that users can visualize and evaluate vegetation dynamics across space and over time. Examples of its recent use include determining rangeland conditions in the context of drought-induced losses for ranchers and related disaster assistance and improving the placement and timing of both vegetation surveys and invasive plant eradication efforts.

HTTPS://DROUGHTVIEW.ARIZONA.EDU/

Other Funding: NOAA National Weather Service Advanced Hydrologic Prediction Service, NOAA-Sectoral Applications Research Program; NOAA-National Integrated Drought Information System; Water, Environmental, and Energy Solutions, The University of Arizona; and USDA-Regional Climate Hub; NIDIS – Coping with Drought; Arizona Remote Sensing Center; Arizona Space Grant Consortium; NASA USGS Land Processes Distributed Active Archive Center (LP DAAC); PRISM Climate Group

Western Region Climate Services Database Development

CLIMAS Investigators: A. Meadow, B. McMahan, and G. Owen

PHOTO: ZACK GUIDO.

Abstract: Adapting to climate change requires that decision makers have information that is relevant to solve their problems at hand. Decision makers do not often have the information they need to make decisions. Unfortunately, potential users of climate information often do not know where to look for relevant information, nor are producers of climate information well connected to potential users, resulting in a gap that separates the supply and demand of climate information. The research efforts in this project represent a first attempt to reduce the gap between the supply of and demand for climate information by creating a comprehensive database of climate service providers in the western U.S.

Selected Deliverables: The Western Region Climate Service Providers Database is a searchable database containing all the public sector and non-profit climate service provider organizations in NOAA's Western Region that were identified by the project team.
HTTP://WRCC.DRI.EDU/CLIMSVCPROVIDERS/

Other Funding: NOAA-Western Regional Partnership; NOAA Regional Climate Services Directors (RCSD)

Preparing for High-Consequence, Low-Probability Events: Heat, Water & Energy in the Southwest

CLIMAS Investigators: S. LeRoy, G. Garfin, B. McMahan, M. Black, and K. Jacobs

PHOTO: KEN LUND.

Abstract: Higher summer temperatures projected for the Southwest will increase the demand for energy, especially during periods of peak load, and the interactions between energy and water systems create additional vulnerabilities, including cascading impacts that affect public health and safety. The complexity of interactions requires consideration of the complete system to adequately assess risks, determine knowledge gaps, and prioritize research agendas to fill these gaps.

Findings: This project helped foster communication between emergency managers, whose time frame of concern is usually on the hour to week timescale, and resource managers, whose frame of concern is usually on the seasonal to decade timescale. Reconciling imminent risks with long-term likelihoods of increased risk was a key insight and challenge. This finding fits well with an ongoing international research challenge: reconciling disaster risk reduction planning with climate adaptation planning.

Other Funding: U.S. Bureau of Reclamation

Drought

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

CLIMAS Investigators: D. Ferguson, M. Crimmins, and T. McKellar

Abstract: This project involves working with the Hopi Tribe's Department of Natural Resources to develop a set of drought indicators and approaches for collecting, analyzing, and utilizing the data needed to support each indicator. Investigators developed an approach to evaluate drought indices in lieu of having systematically collected drought impact data.

Findings: Long-term (1950-2015), daily resolution soil water profile climatologies were developed for four locations including Winslow, AZ, Tucson, AZ, Albuquerque, NM, and El Paso, TX. A monthly scale standardized soil moisture index was developed for each of these locations to enable direct comparison with the monthly soil potential index (SPI) and the standardized precipitation evapotranspiration index (SPEI). Correlations between the different indices indicate consistent results across the four different locations. Results indicate that specific SPI timescales (e.g., 2 month SPI for 10cm soil moisture) can be used to estimate soil moisture related drought impacts consistently across the Southwest U.S.

Selected Deliverables: A final project report was delivered to the Hopi Department of Natural Resources. See Ferguson et al. 2017. *Drought Monitoring to Support Planning for the Hopi Tribe*.

Results were also communicated to the academic community via Crimmins et al. 2017. Discerning 'flavors' of drought using climate extremes indices. *Journal of Applied Meteorology and Climatology* 56:989-1001.
DOI:10.1175./JAMC-D-16-0270.1

Other Funding: NOAA-Sectoral Applications Research Program; NIDIS – Coping with Drought

Sectoral Impacts of Drought and Climate Change

CLIMAS Investigators: G. Frisvold and A. Saito

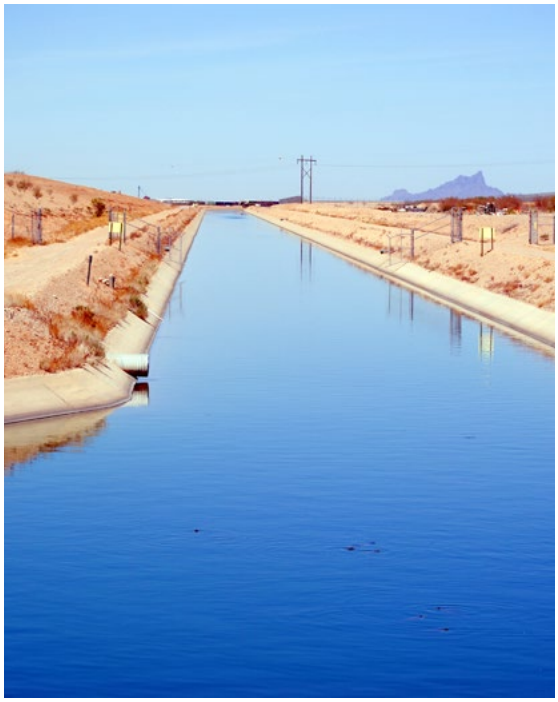
GRAND CANYON NATIONAL PARK TOURISM CREATES OVER $467 MILLION IN ECONOMIC BENEFIT. PHOTO: NATIONAL PARKS SERVICE.

Abstract: This project examines the impacts of drought and climate change on climate sensitive sectors in the Southwest, focusing on agriculture as well as outdoor recreation and tourism. In response to frequent stakeholder requests, the project investigates how water transfers would affect the local economies or rural, water-exporting communities. The project examines how drought and climate change would affect the acquisition of water for environmental restoration. It also considers how combining agronomic information with seasonal weather forecasts can assist the use of option contracts to reduce water-supply risks.

Findings: Costs of cotton crop abandonment can be very high in drought years (e.g., between 40 and 50 percent of net farm income). Access to irrigation significantly reduces abandonment risks. Abandonment in significantly affected by distinct effects of seasonal precipitation and how much precipitation deviates from long-run averages. The researchers found that temperature, overall, was not an important predictor of abandonment.

Other Funding: NIDIS – Coping with Drought; U.S. Geological Survey; U.S. Bureau of Reclamation; U.S. National Park Service; Cotton Incorporated; Yuma County Arizona Cooperative Extension; NOAA Regional Climate Centers (RCC); USDA Hubs

Economics & Livelihoods



CENTRAL ARIZONA PROJECT. PHOTO: LILY HOUSE-PETERS.

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

CLIMAS Investigators: G. Frisvold, T. Bai, and W. Wang

Abstract: This project examines the role of water management information and irrigation technologies in agricultural adaptation to climate variability and changes in the 17 western-most 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; and (c) how climate affects choice of irrigation technologies.

Findings: From 1984 to 2013 (the most recent survey year), water applications to cotton in California, Arizona, and New Mexico fell by more than 3.9 million acre-feet (MAF). This 71-percent reduction in water use is equivalent to 68 percent of total residential water use in the region. Growers want to document trends in their adoption of water conservation practices in response to water scarcity.

Other Funding: NIDIS – Coping with Drought

THE DAVIS-MONTHAN SOLAR ARRAY PROJECT IS PLACED ON 170 ACRES OF UNDERUTILIZED LAND, MAKING THIS THE LARGEST OF ITS KIND ON ANY U.S DEPARTMENT OF DEFENSE INSTALLATION. PHOTO: USAF.

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

CLIMAS Investigators: B. McMahan, A. Barnhart, M. Crimmins, D. Ferguson, and G. Owen

Abstract: The Arizona Business Resilience Initiative is developing a methodology for assessing business opportunities and managing risks to operations associated with climate change and climate variability. This research answers two questions: Based on the current state-of-knowledge in climate change impacts and vulnerability assessment, what are the most probable impacts on the company's operations and projections due to climate change, and with an understanding of the possible impacts, what are actions that can be taken to anticipate or mitigate these risks, or to position the company to take advantage of new opportunities that anticipate and adapt to climate change?

Findings: Utility sector concerns regarding climate change reflect a complex relationship between infrastructural components of the built environment and the climate risks these components help buffer. Changing temperatures will increase electricity demand during summer, but issues such as changing seasonality, water availability, direct and indirect risks to infrastructure, and energy portfolio decisions create a more intricate set of decision paths within these risks and exposures.

Other Funding: Office of Research and Discovery and the Senior Vice President for Research, The University of Arizona

Health

A LARGE DUST STORM APPROACHES PHOENIX, AZ FROM THE SOUTH. PHOTO: ALAN STARK.

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

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

Abstract: Phase 1 of this project included conducting a vulnerability assessment of Arizona residents to climate change-related impacts from vector-borne diseases and valley fever. This effort supported the Arizona Department of Health Services Building Resilience Against Climate Effects (BRACE) program.

Phase 2 will apply future climate to the empirically derived development rates to project future vector abundance. By limiting the discussion to changes in entomologic risk, the focus shifts to the piece of the puzzle with the most quantitative data available.

Selected Deliverables: Two reports regarding climate connections to vector-borne diseases and valley fever were prepared for the Arizona Department of Health Services and the U.S. Center for Disease Control and Prevention Climate-Ready States and Cities Initiative.

Other Funding: Centers for Disease Control and Prevention; Arizona Department of Health Services

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

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

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

Deliverables: This project catalyzed new activities and new partnerships between climate scientists, public health practitioners, and urban planners, leading to continuing research, stakeholder partnerships, and social learning.

Other funding: NOAA National Weather Service; NOAA Regional Climate Services Directors (RCSD); Texas Tech University; University of Texas at El Paso (CERM)

A HABOOB. LAS CRUCES, NM.. PHOTO: DAVID DUBOIS.

Air Quality and Climate

CLIMAS Investigators: D. DuBois, E. Smith, R. Armenta, Y. Zhao, A. Arredondo, and Z. Ghodsizadeh

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

Findings: This year, researchers completed designing a method to characterize dust storm events using data from the North American Regional Reanalysis model archive. Based on 60 dust storm events, they generated a pattern to compare with non-dust days. The resulting pattern can help identify possible dust storm days during other years and can be used as forecast guidance for future dust storms.

Other Funding: New Mexico Department of Health; NOAA National Weather Service; NIDIS – Coping with Drought

ARTIFICIAL CONTAINERS CAN SERVE AS HABITATS FOR IMMATURE MOSQUITOES. THE LARVAE IN A GLASS JAR WITH RAIN WATER. PHOTO: JAMES GATHANY, CDC.

Climate and Health

CLIMAS Investigators: H. Brown, A. Comrie, and M. Arora

Abstract: Climate change and variability strongly control the population dynamics of disease vectors such as mosquitoes, altering their location and seasonality and possibly increasing the risk of disease transmission to humans. This project developed and implemented a climate-based Dynamic Mosquito Simulation Model (DyMSiM) to understand and project climate effects on mosquito population dynamics and associated implications for public health. Results will help climate-health scientists and public health decision makers better understand and project the role of climate in actual disease cases.

Selected Deliverables: Two publications were produced related to the DyMSiM model:

Brown, H., R. Barrera, A. Comrie, and J. Lega. 2017. Effect of temperature thresholds on modeled Aedes aegypti population dynamics. Journal of Medical Entomology. DOI:10.1093/JME/TJX041

Lega, J., H. Brown, and R. Barrera. Aedes aegypti abundance model improved with relative humidity and precipitation-driven egg hatching. Journal of Medical Entomology. In press. DOI:10.1093/JME/TJX077.

2016-2017 Publications

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Ferguson, D., M. Crimmins, A. Masayesva, A. Meadow, J. Weiss, and H. Faulstich. 2017. *Drought Monitoring to Support Planning for the Hopi Tribe*. Final Report from 2010-2016 Collaboration between the Hopi Department of Natural Resources and the Climate Assessment for the Southwest. Tucson, AZ: Climate Assessment for the Southwest.

Frisvold, G. and T. Bai. 2016. Irrigation technology choice as adaptation to climate change in the western United States. *Journal of Contemporary Water Research & Education* 158(1):62-77. HTTP://ONLINELIBRARY.WILEY.COM/DOI/10.1111/J.1936-704X.2016.03219.X/FULL

Garfin, G., S. LeRoy, and H. Jones. 2017. Developing an Integrated Heat Health Information System for Long-Term Resilience to Climate and Weather Extremes in the El Paso-Juárez-Las Cruces Region. Tucson, AZ: Institute of the Environment, 63 p. HTTP://DOI.ORG/10.7289/V5930R6Q

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SIERRA VISTA NATIONAL RECREATION TRAIL IN SOUTHWESTERN NEW MEXICO. PHOTO: BUREAU OF LAND MANAGEMENT.

FRONT AND BACK COVER PHOTO: DANIEL FERGUSON.