



June 1, 2015–May 31, 2016
ANNUAL PROGRESS REPORT



ADAPTING TO CLIMATE VARIABILITY, THRESHOLDS, AND EXTREMES IN THE SOUTHWEST



TUCSON SUNSET. PHOTO CREDIT: ZACK GUIDO.

2015–16 CLIMAS Team

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TABLE OF CONTENTS

1 REGIONAL INTEGRATED SCIENCES AND ASSESSMENTS (RISA)

2 CLIMATE ASSESSMENT FOR THE SOUTHWEST (CLIMAS)

3 CLIMAS BY THE NUMBERS

4 2015-16 HIGHLIGHT

5 NEW CLIMATE SERVICES 2015–16

6 NEW AREAS OF RESEARCH AND PARTNERSHIP

9 SELECTED RESEARCH FINDINGS

11 OUTREACH ACTIVITIES

13 KEY PUBLICATIONS

15 SELECTED APPLICATIONS OF CLIMAS WORK

17 2015 CLIMATE & SOCIETY FELLOWS

19 2016 Fellows

20 EVALUATION EFFORTS

21 CLIMAS CONTRIBUTIONS TO THE NIDIS REGIONAL DROUGHT EARLY WARNING SYSTEM 2015-16

22 CLIMAS PROJECTS: AREAS OF FOCUS

23 Adaptation & Vulnerability

26 Climate Science

27 Communicating Science

28 Decision Support

32 Drought

33 Economics & Livelihoods

35 Education & Evaluation

36 Health

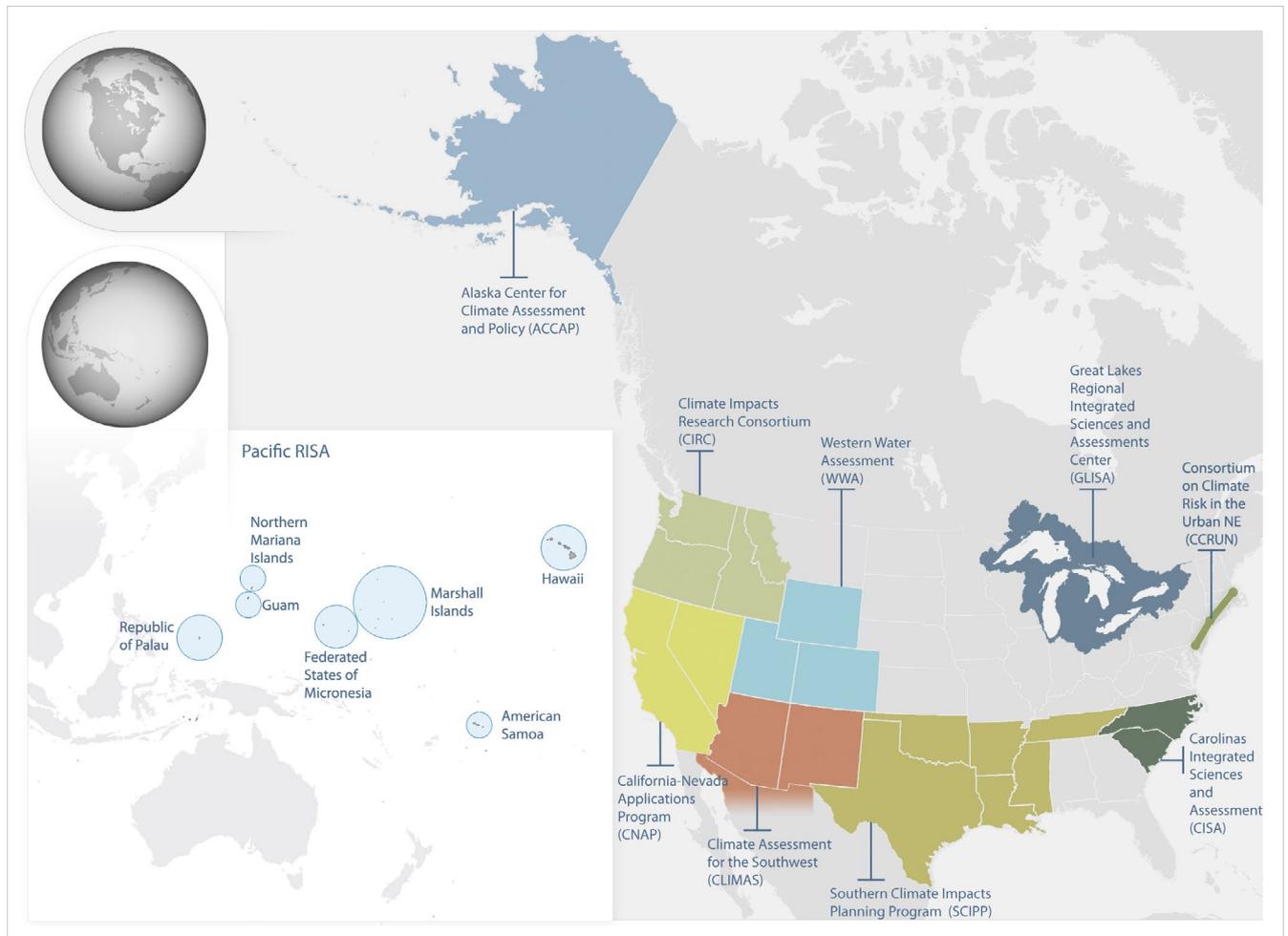
38 PUBLICATIONS

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.



[HTTP://CPO.NOAA.GOV/CLIMATEPROGRAMS/CLIMATEANDSOCIETALINTERACTIONS/RISAPROGRAM.ASPX](http://cpo.noaa.gov/climateprograms/climateandsocietalinteractions/risaprogram.aspx)



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 2015 and May 2016.

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.

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

- Further expansion into public health through the BRACE initiative (Building Resilience Against Climate Effects) and investigating climate impacts on vector-borne diseases ([PAGE 36](#)).
- Assessing the climate information needs of the New Mexico Department of Transportation, which has concerns regarding dust storms and highway travel safety ([PAGE 16](#)).
- Investigating the effects of increasing temperatures and extreme heat on the Southwest's present and future sustainability. After analyzing CMIP-5 climate models, a local power utility incorporated this information into its strategic planning efforts ([PAGE 24](#)).
- Collaborating with Hopi and Navajo land management agencies to inform tribal nation drought planning efforts ([PAGE 32](#)).
- Investigating the climate information sources that irrigators use to make decisions ([PAGE 33](#)).



PECOS RIVER. PHOTO CREDIT: DAVID DUBOIS.

CLIMAS BY THE NUMBERS IN 2015-16

 **1,207**
Instances of CLIMAS Research Mentioned by Media

 **27**
Climate Briefings Disseminated

 **12**
Podcasts Recorded

 **2**
Testimonies Given to U.S. House of Representatives

 **59**
Presentations Given to Stakeholder and Academic Audiences

 **19**
Academic Articles Published.

 **11**
Online Tools Developed

 **16**
Workshops and Trainings Facilitated

 **1**
Book Published

 **9**
YouTube Videos Produced

 **1**
News Article Written

 **57**
Blog Posts Written

 **14**
Stakeholder Reports Produced

 **4**
Databases Created

EL NIÑO WATCH, MAR 2014 – FEB 2015

THE POSSIBILITY
DEC 2013 – FEB 2014
Hints of El Niño conditions develop in mid/late 2014, but neutral status remains

THE FALSE START
June 1, 2014 – November 1, 2014
El Niño predicted to emerge by late summer, but the timing keeps getting pushed back.
KEY EVENTS:
September 2014 – Tropical storms Norbert and Odile bring considerable precipitation into the Southwest.
November 2014 – Enhanced Pacific Tropical Storm activity: 14 hurricanes and 8 major hurricanes (category 3 or higher).

THE DISAPPOINTMENT
December 1, 2014 – February 1, 2015
Forecasts predict a weak El Niño event, if it happens at all.



ON THE HORIZON
March 1, 2014 – May 1, 2014
Increasing probability of El Niño conditions in seasonal forecasts and models.
KEY EVENTS:
May 2014 – Hurricane Amanda brings a very early start to the Pacific tropical storm season.



ORGAN PIPE NATIONAL MONUMENT. PHOTO CREDIT: ZACK GUIDO.

One of CLIMAS’ top accomplishments this year was responding to information needs regarding the 2015-16 El Niño event. CLIMAS investigators organized a coordinated outreach effort in the months leading up to, during, and after El Niño. Through the *Southwest Climate Outlook*, climate podcasts, the Southwestern Oscillations blog, and the El Niño News & Information Hub, CLIMAS investigators explored:

- a) what was predicted to happen, including forecasts and outlooks, plus the media and public expectations for El Niño;
- b) what actually happened, including weather data and descriptions and case studies from people’s experiences of the event; and
- c) how stakeholders will use climate data and seasonal outlooks in the future.

Several investigators were interviewed by local, regional, and national media outlets about what El Niño meant for the Southwest, demonstrating CLIMAS as a go-to source for regional climate information.

EL NIÑO ADVISORY, MAR 2015 – APR 2016

THE INTENSIFICATION

June 1, 2015 – September 1, 2015
 Summer forecasts see increasing evidence of a strong event.

KEY EVENTS:

June 2015 – Early season tropical storm activity (Blanca & Carlos) bring widespread precipitation to the Southwest

A RECORD OR NEAR-RECORD EVENT

October 1, 2015 – January 1, 2016
 This El Niño ranks among the top 3 strongest events.

KEY EVENTS:

October 2015 – Patricia is the strongest hurricane on record in the eastern North Pacific basin, and most of the Southwest records well above average precipitation in October.

January 2016 – Run of storms in early January offer a preview of what El Niño might bring.

FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR

2016

THE COMEBACK

March 1, 2015 – May 1, 2015
 Increasing confidence that El Niño will last through 2015, with hints of a strong El Niño event.

KEY EVENTS:

May 2015 – May 2015 is cooler and wetter across the region.

AN UNDERWHELMING PERFORMANCE

February 1, 2016 – April 1, 2016
 El Niño conditions remain, but the Southwest receives much less El Niño associated rainfall than expected.

KEY EVENTS:

February 1 – March 1, 2016 – February and March are below normal to record-dry across much of the Southwest. Temperatures are well above average.

April 1, 2016 – Water year precipitation totals (Oct 1 - Apr 2016) are average to below average across Arizona and western New Mexico and above average in eastern New Mexico, but these totals are buoyed by tropical storm activity from October 2015.

NEW CLIMATE SERVICES 2015–16



TEP SOLAR ARRAY.

Arizona

The Arizona Business Resilience Initiative: Part of this project involved conducting an assessment with an electric utility in southern Arizona targeted at heat, water availability, wildfire risk, and air quality concerns. The analysis was co-produced with utility employees and integrates spatial data. The utility has used this information in revising their strategic resource plans such as energy portfolios, infrastructure planning, and land-use questions.



RIO GRANDE GORGE. PHOTO CREDIT: DAVID DUBOIS.

New Mexico

The Rio Grande-Bravo Outlook: 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](http://www.climas.arizona.edu/rgbo)



HURRICANE LINDA, 2015. PHOTO CREDIT: NASA, LANCE/EOSDIS RAPID RESPONSE, CAPTURED ON AQUA SATELLITE.

Southwest Region:

El Niño News & Information Hub: This climate service product is a repository for background information, news, and commentary regarding observed and expected El Niño impacts in the Southwest U.S. The hub was initiated in fall 2015 to help regional stakeholders prepare for the potential impacts of a strong El Niño event.

[HTTP://WWW.CLIMAS.ARIZONA.EDU/SW-CLIMATE/EL-NIÑO-SOUTHERN-OSCILLATION](http://www.climas.arizona.edu/sw-climate/el-niño-southern-oscillation)



EL PASO SKYLINE.



PHOTO CREDIT: CALVIN JOHNSON

National Integrated Heat Health Information System – El Paso Region

CLIMAS Investigator: G. Garfin

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 by: a) identifying key heat health parameters and target populations for heat health early warning; b) creating a calendar of climate- and weather-related public health decisions; c) assessing capacity for coordinated heat health early warning; d) facilitating the sharing of best practices; and e) initiating development toward a community of practice within a network of regional cities.

Importance: This project explicitly connects CLIMAS with the NOAA-CDC National Integrated Heat Health Information System initiative and with an international network of similar projects aimed at implementing the Global Framework for Climate Services.

Other funding: NOAA National Weather Service, NOAA Regional Climate Services Directors, Texas Tech University, and University of Texas at El Paso.

Views of Drought across the Cattle Ranching Communities of Southwestern New Mexico and Northwestern Chihuahua

CLIMAS Investigator: D. DuBois

This project documents the historical and current drought status of rangeland areas used for cattle ranching across Southwestern New Mexico and Northwestern Chihuahua. Interviews will be conducted with ranchers in the US and Mexico facing these challenges. Interviews will be recorded, translated into English, edited, and included in a short video documentary. A report will accompany the video with data on the drought on both sides of the border and summaries of the interviews.

Importance: This project lays the groundwork for an assessment of drought impacts and needs for cattle ranchers in the Lower Rio Grande.

Other funding: NIDIS – Coping with Drought.



POWERLINES WITH WINDMILLS



FLOODING THAT OCCURRED IN AND AROUND THE SOUTH PLAINS MALL IN SOUTHWEST LUBBOCK, TX.. PHOTO CREDIT: NOAA.

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

CLIMAS Investigators: G. Garfin and S. LeRoy

Higher summer temperatures projected for the Southwest will increase the demand for energy, especially during periods of peak load. Interactions between energy and water systems create additional vulnerabilities, including cascading impacts that affect public health and safety. A regional group of researchers and resource managers with expertise in water, energy, climate, natural hazards, and emergency management met on September 28-29, 2015, to address management of and preparedness for high-impact, low-probability events.

Importance: This project brought together managers and researchers across various disciplines to discuss a topic that has not typically been considered when planning for extreme events—planning for unlikely scenarios that have the potential for very large, cascading impacts.

Other funding: U.S. Bureau of Reclamation.

Western Region Climate Services Database Development

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

Adapting to climate change requires that decision makers have information that is salient, credible, and legitimate. 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 United States.

Importance: This project was initiated at the request of the NOAA Western Region Climate Services director, who was looking for guidance about ongoing climate service activities in the region. The project evolved into a searchable public database that allows those seeking climate services to easily access information about regional providers.

Other funding: NOAA Regional Climate Services directors, NOAA Regional Climate Centers.



THE FOOD BANK OF SOUTHERN ARIZONA FARMER'S MARKET. PHOTO CREDIT: GIGI OWEN.

Evaluating Climate Change Adaptation in Tucson, AZ

CLIMAS Investigator: G. Owen

This project evaluates three case studies that address present and future risks and vulnerabilities related to climate change, focusing on the consumption of and access to food, water, and energy. One case study addresses current and future food security issues among children in Tucson, Arizona. The second assesses an electric utility company's process to ensure a reliable energy source for Tucson residents. The third case analyzes Tucson's initiatives for implementing green infrastructure for stormwater catchment and reuse.

Importance: The climate change adaptation community has identified a need to evaluate adaptation projects to help ground adaptation in practice rather than in theory. Frameworks for evaluating adaptation are in development. This project helps inform the best practices for evaluating adaptation.

SELECTED RESEARCH FINDINGS



ORGAN PIPE NATIONAL MONUMENT. PHOTO CREDIT: ZACK GUIDO.

1 Adaptation Strategies for Water and Energy Sectors in the Southwest

CLIMAS Investigators: B. Colby, G. Frisvold, C. Woodhouse, and G. Garfin

- Innovative water trading initiatives are underway in several western states. State legislatures and water management agencies have solicited testimony and requested workshops focused on the economic implications of these initiatives.
- Public agencies and NGOs have a better understanding of how to structure contracts with agricultural participants and how to measure and monitor water "savings" produced by participants.

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

CLIMAS Investigator: G. Frisvold

- Agriculture's water footprint—the amount of water needed to produce a given amount of crop—in the Southwest has declined significantly. Reductions in water use for cotton production have declined by an amount equivalent to two-thirds of all residential water use in those states.
- Improvements in local hydrological data reveal that earlier estimates regarding the water footprint of Arizona wheat production were wrong. Due to high yields and adjustments in seasonal production patterns to conserve water, Arizona now has one of the world's smallest water footprints.
- Climate information systems have shown great promise in improving irrigation management and adaptation to climate variability, but the many farmers who have limited access to the Internet may seldom use web-based information systems.

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

CLIMAS Investigator: B. McMahan

- Acute heat waves and exposure remain a fundamental concern for vulnerable populations but ongoing project work continues to elaborate on chronic or long-term issues associated with climate and environmental risk in the Southwest, which intersect and amplify the acute risks that operate on shorter time frames.



4 **Western Region Climate Services Database Development**

CLIMAS Investigator: A. Meadow

- Most climate service providers included in this database (79/136) are focused on delivering climate and weather information. A much smaller percent of providers appear to be offering services related to interpreting or applying that information.
- In comparison to the number of tribes in NOAA's Western Region (231 tribes), only 17 climate service providers target their services or information to tribes.

5 **Southwest Climate Gap**

CLIMAS Investigators: M. Wilder, D. DuBois, and B. McMahan

- A significant climate gap exists in the Southwest due to extreme climate conditions coupled with high socioeconomic vulnerability in the region.
- Low-income communities in southern Arizona adapt to extreme heat by staying indoors, which has implications for public health and sustainability.

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

CLIMAS Investigator: C. Woodhouse

- Major upper Colorado River droughts of the 20th and 21st centuries have occurred under various combinations of precipitation, temperature, and prior fall soil moisture.
- The 2000s drought (2000–12) was the least dry (precipitation at the 48th percentile), but the warmest (79th percentile). The 1988–96 drought was also only moderately dry but quite warm.

OUTREACH ACTIVITIES



PHOTO CREDIT: JO VASQUEZ.

CLIMAS Website ([WWW.CLIMAS.ARIZONA.EDU](http://www.climas.arizona.edu))

General website summary: From June 1, 2015–May 31, 2016, the CLIMAS website had approximately 90,000 page views

- The Southwest Climate pages garnered 30 percent of total traffic, while 14 percent of traffic went to the publications pages. Eleven percent of traffic was directed towards the *Southwest Climate Outlook*, 8 percent for the Southwestern Oscillations blog, 4 percent for research and project pages, and 2 percent for the podcast.
- The top sub-domains of the website focused on interest in the ongoing El Niño event (15 percent of total traffic); the monsoon (17 percent of total traffic); and Southwest temperature, precipitation, and drought (~7 percent of total traffic).

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

Climate Investigators: B. McMahan, M. Crimmins, G. Garfin, D. Ferguson, G. Frisvold, H. Brown, E. Huddleston, Z. Guido, 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.

The blog reinforced this year's pattern of increased interest about El Niño; the most trafficked post was an extended explanation of the potential impact of a strong El Niño event on the Southwest. A number of other posts saw more normal traffic, with 100 to 500 visits per blog post. [HTTP://WWW.CLIMAS.ARIZONA.EDU/BLOG](http://www.climas.arizona.edu/blog)

El Niño News & Information Hub

Climate Investigators: Ben McMahan, M. Crimmins, E. Huddleston, G. Owen, and H. Brown

The El Niño News & Information Hub connects climate information to potential and observed impacts of the 2015–16 El Niño event. This project integrates multimedia outreach (web, podcast, blog, and print) with climate assessment and analysis to create content that might be of interest to other scientists, resource managers, policymakers and decision makers, and an interested public. This year, 10 unique pieces of content were produced in addition to the El Niño Tracker in the *Southwest Climate Outlook* and the Southwest Climate Podcasts.

The hub experienced higher traffic around times of increased forecast frequency and media attention (fall 2015), tropical storm activity tied to El Niño (October–November 2015), and early 2016 storms that were attributed to El Niño (January 2016).

Southwest Climate Podcasts

Climate Investigators: B. McMahan, M. Crimmins, G. Frisvold, B. Colby, D. Ferguson, G. Garfin, E. Huddleston, 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 and special podcast series. 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.

[HTTP://WWW.CLIMAS.ARIZONA.EDU/MEDIA/PODCASTS](http://www.climas.arizona.edu/media/podcasts)

- Southwest Climate Podcast is produced monthly, synthesizing information from disparate sources, and translating national and global discussions into what they mean for the Southwest.
- Southwest Climate Update-Mini Podcast focuses on quick and timely reporting of important climate news and information. It emphasizes stories that relate to the Southwest that illustrate the impact of climate on national or global scales. This podcast is also released as a video on the CLIMAS YouTube channel.
- Speaking of Climate... includes conversations with researchers and stakeholders about climate-related issues. Distributed on the CLIMAS listserv, CLIMAS blog, Twitter, Facebook, and YouTube.

Other funding: NIDIS – Coping with Drought.

The Southwest Climate Outlook

Climate 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.

Other funding: NIDIS – Coping with Drought.

Outreach Interactions on Social Media

June 1–Aug. 30, 2015: Notable engagements on social media during this three-month period centered on regional/seasonal climate forecasts, El Niño-specific forecast discussions, and specific outlier events. Some of the most notable interactions on social media were in response to El Niño forecasts and reflect the anticipation for a not-yet-started El Niño event that was building in strength.

Sept. 1–Nov. 30, 2015: Notable engagements centered on El Niño, given the forecast potential of a record to near-record event, and on discussion about a specific tropical storm event that produced impressive moisture totals in the region. The National Weather Service (NWS) office in Tucson (@NWSTucson) used CLIMAS graphics on their Twitter feed to review the end of the 2015 monsoon.

Dec. 1, 2015–Feb. 29, 2016: Notable engagements centered on the performance of El Niño to date, as this three-month window began to capture some of the increased winter storm activity as well as the subsequent disappointment about the performance of El Niño. Top engagements focused on the relative “average” status of the winter’s precipitation and whether this met expectations for the season. The partnership with the Rio Grande-Bravo Climate Outlook also began to generate activity and dialogue.

Mar. 1–May 30, 2016: This three-month window showed a notable shift towards disappointment and retrospective analysis of the El Niño event, based on how it performed compared to expectations, as well as ongoing commentary as to how far this particular event deviated from general expectations, specific models, and seasonal outlooks.

KEY PUBLICATIONS



PHOTO CREDIT: DANIEL FERGUSON.

Routson C., **J. Overpeck**, **C. Woodhouse**, and W. Kenney. 2016. Three Millennia of Southwestern North American Dustiness and Future Implications. *PLOS ONE* 11(2):e0149573.

A 3,000-year record of drought and atmospheric dust loading indicates that multi-decadal drought can cause widespread destabilization of vegetation and soils, yielding increases in regional dust loading of the type that can cause human health issues and decreases in Colorado River flow.

Woodhouse, C., G. Pederson, K. Morino, S. McAfee, and G. McCabe. 2016. Increasing influence of air temperature on upper Colorado River streamflow. *Geophysical Research Letters* 43. DOI:10.1002/2015GL067613.

This article uses paleoclimatic data for the Colorado River Basin 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 to determine how warming temperatures may influence river flow and water supply in the future.

Frisvold, G. 2015. Water, Agriculture, and Drought in the West Under Changing Climate and Policy Regimes. *Natural Resources Journal* 55:293-328. [HTTP://LAWSCHOOL.UNM.EDU/NRJ/VOLUMES/55/2/NRJ-55-2-FRISVOLD.PDF](http://lawschool.unm.edu/nrj/volumes/55/2/nrj-55-2-frisvold.pdf).

Technological fixes to conserve and transfer agricultural water to other uses will likely fail to facilitate climate adaptation unless changes in water management institutions, policies, and economic incentives accompany those technological fixes. The article provides information on agriculture, water, and climate adaptation to western lawyers and law students. It also provides information to the USDA about barriers to the adoption of climate adaptation information from their climate hubs.

Duval, D. and **B. Colby**. 2015. *The Influence of Colorado River Flows on the Upper Gulf of California Fisheries Economy*. Report to the Sonoran Institute, July.

This report examines existing and potential economic effects and values for Upper Gulf of California marine ecosystems as linked to the effects of freshwater flows from the lower Colorado River and the implementation of Minute 319 in providing flows. It provides a methodological framework for measuring economic effects of having higher flow levels and the implications for Upper Gulf communities.

Brown, H., A. Young, J. Lega, T. Andreadis, J. Schurich, and A. Comrie. 2015. Projection of climate change influences on U.S. West Nile virus vectors. *Earth Interactions* 19:1-18. DOI: [HTTP://DX.DOI.ORG/10.1175/EI-D-15-0008.1](http://dx.doi.org/10.1175/EI-D-15-0008.1).

This article provides location-specific information about West Nile virus mosquito abundance as it relates to climate.

Meadow, A., Z. Guido, M. Crimmins, and J. McLeod. 2016. From principles to action: Applying the National Research Council's principles for effective decision support to the Federal Emergency Management Agency's watch office. *Climate Services* 1:12-23. DOI: [10.1016/J.CLISER.2016.02.002](https://doi.org/10.1016/j.cliser.2016.02.002).

This paper describes the methods used for planning and executing a three-party collaborative effort to provide climate services, a decision support tool developed through this process, and the lessons taken from this collaborative process.

Kavouras, I., **D. DuBois**, G. Nikolich, A. Corral Avittia, and V. Etyemezian. 2015. Particulate dust emission factors from unpaved roads in the U.S.-Mexico border semi-arid region. *Journal of Arid Environments* 124:189-192. DOI: [HTTP://DX.DOI.ORG/10.1016/J.JARIDENV.2015.07.015](http://dx.doi.org/10.1016/j.jaridenv.2015.07.015).

Fugitive dust in the border cities of Las Cruces, New Mexico; El Paso, Texas; and Ciudad Juarez in Mexico presents challenges for air quality managers due to their variability in space and time. The study was conducted to provide site-specific PM10 emission rates of unpaved roads in areas that have been deemed problematic by local authorities and the public.

Ferguson, D., A. Masayeva, A. Meadow, and M. Crimmins. 2016. Rain gauges to range conditions: Collaborative development of a drought information system to support local decision making. *Weather, Climate and Society*. Early online release. [HTTP://DX.DOI.ORG/10.1175/WCAS-D-15-0060.1](http://dx.doi.org/10.1175/WCAS-D-15-0060.1).

This paper reports on collaborative work with the Hopi Tribe to develop a drought information system that: 1) is based on how drought is experienced by Hopi citizens and resource managers; 2) incorporates local observations of drought impacts as well as conventional indicators; and 3) brings together local expertise with conventional science-based observations.

Wilder, M., D. Liverman, L. Bellante, and T. Osborne. 2016. Southwest climate gap: Poverty and environmental justice in the U.S. Southwest. *Local Environment: The International Journal of Justice and Sustainability* 1-22. DOI: [HTTP://DX.DOI.ORG/10.1080/13549839.2015.1116063](http://dx.doi.org/10.1080/13549839.2015.1116063).

How does the southwestern climate—especially heat/cold extremes and precipitation associated with El Niño—affect low-income populations and communities of color in the Southwest? This article answers this question by analyzing 20 interviews that were conducted with 15 organizations that provide services to low-income populations.

LeRoy, S., G. Garfin, and M. Black. 2016. Anticipating Cascading Effects from Climate Extremes. *EOS* 97. DOI: [10.1029/2016EO048971](https://doi.org/10.1029/2016EO048971).

This meeting report outlines the High-Consequence, Low-Probability workshop held in fall 2015. It summarizes the key findings, including research, management, and planning priorities identified by participants.

[HTTPS://EOS.ORG/MEETING-REPORTS/ANTICIPATING-CASCADING-EFFECTS-FROM-CLIMATE-EXTREMES](https://eos.org/meeting-reports/anticipating-cascading-effects-from-climate-extremes).

SELECTED APPLICATIONS OF CLIMAS WORK



FEMALE MOSQUITO.

Climate and Health

Climate Investigators: A. Comrie and H. Brown

This project develops and implements a climate-based Dynamic Mosquito Simulation Model (DyMSiM) to understand and project climate effects on mosquito population dynamics and associated implications for public health. DyMSiM has had a broad impact. Recently it was implemented in a rapid-response study that included University of Arizona colleague Kacey Ernst and CLIMAS alumnus Cory Morin. The study outlined the seasonal occurrence and abundance of the Zika virus vector mosquito for the U.S. Ernst recently gave public testimony to the U.S. House of Representatives Committee on Science, Space and Technology, Subcommittee on Research and Technology regarding current knowledge of *Aedes aegypti* in the U.S. related to the Zika virus.



PHOTO CREDIT: MIKE CRIMMINS.

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

CLIMAS Investigator: M. Crimmins

DroughtView combines geovisualization tools with remote sensing products to detect drought conditions. Engaging the range management and rancher community on this tool heavily over the past year and has yielded positive feedback on the utility of using remote sensing for drought monitoring in remote areas. Ranchers are interested in using the tool to track potential conditions on remote pastures/allotments that are difficult to get to. There is also interest in using DroughtView in formal drought assessments and planning efforts with the U.S. Forest Service.



DUST STORM. PHOTO CREDIT: DAVID DUBOIS.



SAGUARO NATIONAL PARK.

Air Quality and Climate

CLIMAS Investigator: D. DuBois

Dust storms in the Southwest U.S. and northern Mexico continue to be a serious health and safety issue. The construction of a synoptic climatology of these dust storms began this year to increase the ability to forecast these events. The New Mexico Department of Transportation (DOT) has increased its interest in public safety and mitigation of dust. The DOT staff has since requested and obtained federal funding for mitigation and public notification projects.

The Southwest Climate Outlook

CLIMAS Investigator: B. McMahan

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. The reservoir diagrams in the monthly SWCO are used by members of the New Mexico Office of the State Engineer and the Interstate Stream Commission in presentations by the executive director to the New Mexico Legislature.

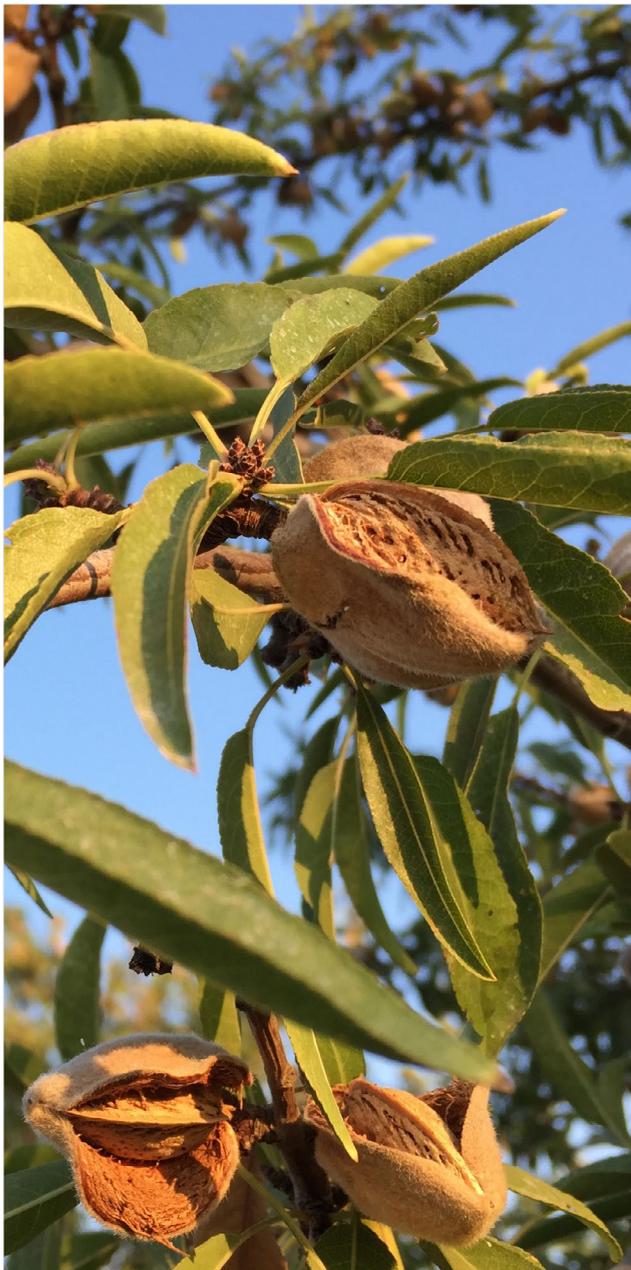


PHOTO CREDIT: DANIEL FERGUSON.

2015 CLIMATE & SOCIETY FELLOWS

The Climate & Society Graduate Fellows Program—funded by the University of Arizona Office of Research and Development and administered by CLIMAS—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 is open to students conducting research anywhere in the world.

The 2015 fellows received funding in January and finished their projects in December. Selected results of their fellowships are included below:



CALIFORNIA ALMOND TREES. PHOTO CREDIT: CHRISTINA GREENE.

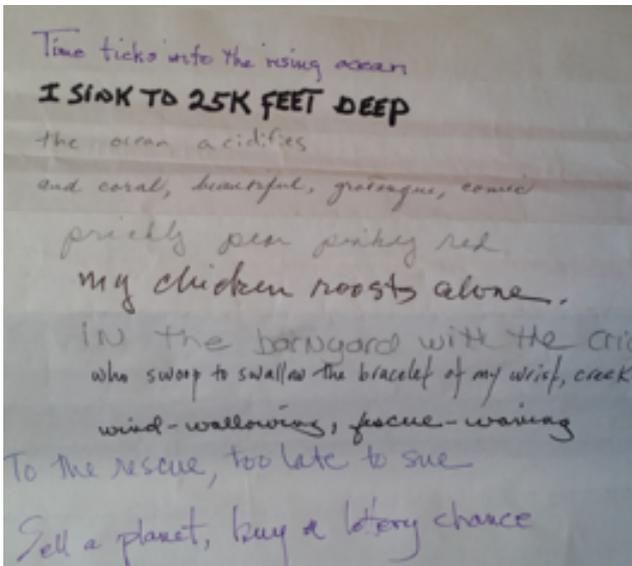
Almonds Fish and a Modern Dust Bowl: Narratives of Drought Vulnerability and Adaption in California's San Joaquin Valley

CLIMAS Investigator: Christina Greene

California is in its fourth year of an extreme drought. Warm temperatures and lack of rainfall have led to decreased snowpack critical for water use by cities and agriculture. The investigator interviewed different agricultural stakeholders to understand how drought impacts and drought vulnerability are experienced in California's San Joaquin Valley. These interviews helped outline four main environmental narratives that frame how physical and social factors produce and intensify drought vulnerability for rural farming communities in the valley. While the different narratives identify different drought "villains," such as environmental regulations or farmers, they hold in common an understanding that investment in agriculture and rural communities is necessary to address drought vulnerability for future droughts in the region.



AN ALMOND FARM IN CENTRAL CALIFORNIA.



EXAMPLE OF "EXQUISITE CORPSE" IN-CLASS WRITING EXERCISE FROM CLIMATE CHANGE & POETRY. EACH CONTRIBUTOR WROTE A LINE ONLY SEEING THE ONE PRIOR LINE, SO THAT THE POEM WOULD ACCRUE IN AN ORGANIC WAY. PHOTO CREDIT: ERIC MAGRANE.

Climate Change & Poetry

CLIMAS Investigator: Eric Magrane

The purpose of this project was to develop and teach a community course on Climate Change & Poetry, one of the first of its kind anywhere. The course took place at the University of Arizona Poetry Center in fall 2015 and included six two-hour classes. Magrane designed the course around the growing body of contemporary poetry that engages with climate change and alternated readings of poetry with readings on climate change. Community participants left the course with an increased awareness of the science and social impacts of climate change as well as a strong awareness of environmental poetry. Outputs from the course include multiple academic presentations and two academic articles that are in preparation. Additionally, the University of Arizona Poetry Center is now planning a full reading series for fall 2016 around climate change.



Toward Increased Energy Efficiency in Tucson: Evaluating an Energy Efficiency Workshop for Tucson Businesses

CLIMAS Investigator: Valerie Rountree

On March 27, 2015, the Tucson mayor's office and Tucson Electric Power held a half-day workshop for local organizations to discuss the economic benefits associated with energy efficiency and financing options for energy efficiency projects. The primary purpose of this project was to evaluate the impacts of this workshop. Specifically, Rountree's objectives were to gather feedback from participants to improve future workshops, and follow up with participants through surveys and interviews to determine whether attending the workshop led to the implementation of energy efficiency measures among participating organizations.

SELECTED RESULTS:

- Survey responses suggest that after the workshop, lack of information was perceived as less of a barrier, while time, job limitations, and cost were perceived as greater barriers.
- Many participants signed their businesses up for energy audits, and some participants had implemented an energy-efficiency project within six months.



FARMER-MANAGED IRRIGATION SYSTEMS IN GANDAKI BASIN, NEPAL. PHOTO CREDIT: BHUWAN THAPA.

Use-Inspired Research On Adaptation Strategies Of Farmer-Managed Irrigation Systems In Gandaki Basin, Nepal

CLIMAS Investigator: Bhuwan Thapa

Nepal has a long history of irrigation water management by farmers. These farmers take sole responsibility for operating and maintaining the irrigation systems. However, these systems are increasingly under stress due to local-, regional-, and global-level changes such as climatic variability, labor out-migration, market pressures, and watershed degradation. The purpose of this project was to conduct a participatory vulnerability assessment of the irrigation systems under stress from climatic variability and natural disasters and support the farmers with the development of appropriate adaptation strategies. Since beginning this research, Thapa has received external funding from the International Center for Integrated Mountain Development's to continue this research as his Ph.D. dissertation, and he is working on a booklet outlining the best practices on adaptation in irrigated agriculture.

SELECTED RESULTS:

- To supply additional water during shortages, farmers have installed community-managed water pumps to lift river water up by as much as 40 feet and distribute it through an existing irrigation distribution system.
- In areas where augmenting additional water is not an option, farmers have switched to less water-demanding crops. Most of the farmers now use hybrid varieties that produce high yield for less water.

2016 Fellows

The 2016 fellows are in the middle of their fieldwork. These students are conducting research with the Black Mesa Water Coalition for off-grid residential solar systems; connecting local knowledge of small hydropower development with environmental policymaking in Chile; assessing local incentives that drive efforts to conserve dryland systems on agricultural landscapes in northern China; developing a community hub for climate innovators in southwest coastal Bangladesh; and working with the Pyramid Lake Paiute Tribe in Nevada to improve water resource planning and evaluate climate adaption strategies.



SALEH AHMED IS NOW CONDUCTING HIS MONTH-LONG FIELD RESEARCH ON LOCAL ADAPTATION TO CLIMATE CHANGE IN SOUTHWEST COASTAL BANGLADESH. PHOTO CREDIT: ABIR RAIHAN.

The CLIMAS program evaluation project has three overarching goals:

- Improve CLIMAS by measuring the impact of specific elements of the program and feeding those results back into program operations.
- Demonstrate the value of CLIMAS by assessing who values the program and how.
- Develop a set of metrics to identify the program's impacts and influence.

Results-to-date:

We are currently collecting data regarding our program-level impact. This long-term data collection will allow us to understand broader program impact from 2012–17. Data collection deliverables to date include:

- A) Outreach: Spreadsheets for each PI regarding media interviews given, online contributions written, presentations given, and workshops conducted. Spreadsheets include basic data, motivating factors, intended audiences, and instances of further interaction for each outreach item.
- B) Education and Training: Database of all graduate students who have interacted with CLIMAS since 2013 as a graduate research assistant, Climate & Society Fellow, or "Connecting Environmental Science and Decision Making" seminar participant.
- C) Advancing Knowledge: Spreadsheets of all peer-reviewed and non-peer-reviewed publications produced since 2012.
- D) Use-inspired science and decision support: Evaluation plans produced for at least one research project for each CLIMAS investigator.

CLIMAS Contributions to the NIDIS Regional Drought Early Warning System 2015-16

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 the following pages.

Convene and collaborate with regional stakeholders.

- Southeast Arizona Agricultural Weather and Climate Working Group

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

- Views of Drought across the Cattle Ranching Communities of Southwestern New Mexico and Northwestern Chihuahua
- 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

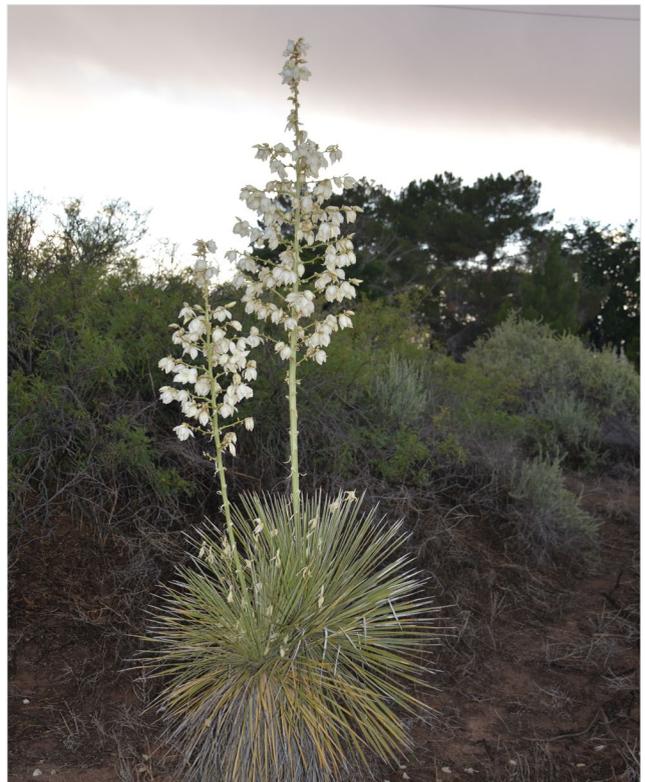
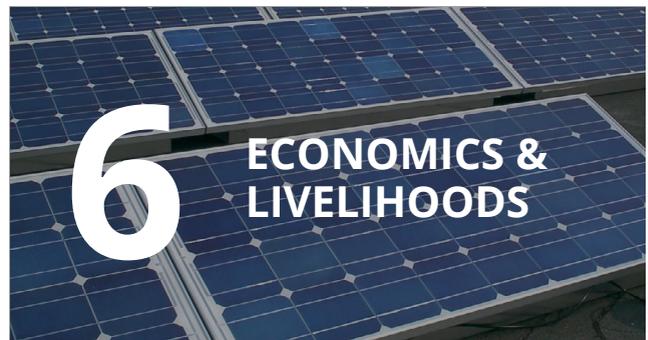
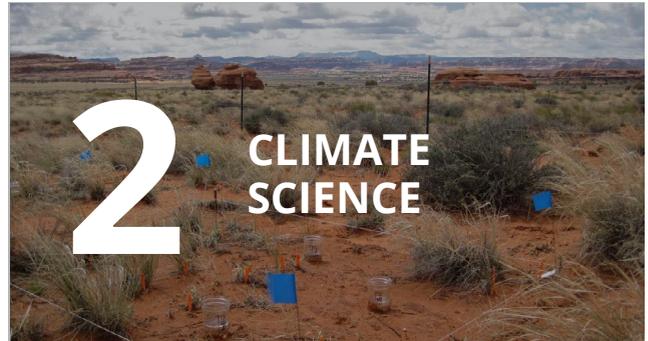


PHOTO CREDIT: JO VASQUEZ.

CLIMAS PROJECTS: AREAS OF FOCUS

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





THE RIO GRANDE. PHOTO CREDIT: JO VASQUEZ.

Adaptation Strategies for Water and Energy Sectors in the Southwest

CLIMAS Investigators: B. Colby, G. Frisvold, C. Woodhouse, G. Garfin, S. Deol, D. Duval, A. Clarke, and T. Duffy

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.

Selected Deliverables:

Publications

Colby, B., J. Ziolkowska, and J. Peterson. (In press). Water Trading Innovations: Reducing Agricultural Consumptive Use to Improve Adaptation to Scarcity. In *Competition for Water Resources: Experiences and Management Approaches in the US and Europe*.

- Cost-effective verification of reduced consumptive use and low transaction cost protocols to implement trades are making temporary and intermittent arrangements more feasible in many areas.

Duval, D. and B. Colby. (In press). Colorado River Flows and the Fisheries Economy of the Upper Gulf of California. *Ecological Engineering*.

- Explores the influence of Colorado River flows into the Upper Gulf of California on fisheries productivity and opportunities to shift water from agriculture to the environment.

Kerna, A., B. Colby, and F. Zamora. (In press). Valuing Environmental Flows in Mexico's Colorado River Delta. *Water Economics and Policy*.

- Reports research findings on values held by visitors from nearby Mexican cities and villages for environmental flows in the Colorado River Delta.

Four stakeholder technical reports for the U.S. Bureau of Reclamation, the Sonoran Institute, and the New Mexico Interstate Stream Commission.

Other funding: NIDIS – Coping with Drought.

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

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

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.

Selected Deliverables:

Presentation

McMahan, B. Extreme Heat Risk: Policy Implications and Local Practice in the Southwest. Society for Applied Anthropology Annual Meeting. Vancouver, British Columbia. April 15, 2016.

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:

Publications

Garfin, G. and S. LeRoy. 2015. Extreme Heat Toolkit – Resources Document. Tucson, AZ: Climate Assessment for the Southwest, 47 pp.

LeRoy, S. and G. Garfin. 2015. Climate Extremes Data and Communication Products for Western Adaptation Alliance Cities in the Intermountain Southwest. Climate Assessment for the Southwest, University of Arizona: Tucson, AZ.

Data Output:

ESRI Story Maps: Each story map highlights specific examples of extreme events in various cities and their impacts since 1960, and provides examples of how cities are preparing for these types of extremes. Includes infographics and a two-page factsheet for each climate extreme.

- Drought in the Intermountain Southwest:
[HTTP://ARCG.IS/1NDY5NO](http://arccg.is/1NDY5NO)
- Fire in the Intermountain Southwest:
[HTTP://ARCG.IS/1G11TPQ](http://arccg.is/1G11TPQ)
- Extreme Floods in the Intermountain Southwest:
[HTTP://ARCG.IS/1DLMY8W](http://arccg.is/1DLMY8W)
- Extreme Heat in the Intermountain Southwest:
[HTTP://ARCG.IS/1BMT9WS](http://arccg.is/1BMT9WS)
- The Many Facets of Wind in the Intermountain Southwest:
[HTTP://ARCG.IS/1GUMIDK](http://arccg.is/1GUMIDK)

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

Abstract: This research addresses the gaps between adaptation theory, planning, and practice by evaluating three case studies in Tucson. The project involves creating and testing an evaluation framework that assesses different approaches to adaptation, including objectives, methods, and outcomes. The evaluation includes three case studies that address present and future risks and vulnerabilities related to climate change, focusing on the consumption of and access to food, water, and energy.

Selected Deliverables:

Presentations

Owen, G. Evaluating Adaptation in Tucson, AZ. RISA Annual Meeting. Tucson, AZ. February 23, 2016.

Owen, G. Evaluating Adaptation in Tucson, AZ. Annual Meeting of the Association of American Geographers. San Francisco, CA. April 2, 2016.

Southwest Climate Gap

CLIMAS Investigators: M. Wilder, D. DuBois, B. McMahan, and E. Schur

Abstract: The Southwest Climate Gap seeks to understand the relationship between climate and poverty in New Mexico and Arizona. This project asks how the southwestern climate affects low-income populations and communities of color in the region by examining acute and chronic climate vulnerability to extreme climate events. This project is part of a broader HEAT project in CLIMAS that aims to better characterize cascading effects of extreme heat events.

Selected Deliverables:

Publication

Wilder, M., D. Liverman, L. Bellante, and T. Osborne. 2016. Southwest climate gap: Poverty and environmental justice in the U.S. Southwest. *Local Environment: The International Journal of Justice and Sustainability* 1-22. [HTTP://DX.DOI.ORG/10.1080/13549839.2015.1116063](http://dx.doi.org/10.1080/13549839.2015.1116063)

Media

Jenney, P. Minding the Climate Gap. Univ. of Arizona - Institute of the Environment. August 19, 2015. [HTTP://WWW.ENVIRONMENT.ARIZONA.EDU/NEWS/MINDING-CLIMATE-GAP](http://www.environment.arizona.edu/news/minding-climate-gap)

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

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

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

Deliverables:

Data Output

K. Hayhoe, with ATMOS Research, conducted a modeling analysis of specific thresholds relative to Las Cruces. She produced many charts showing projections of various climate variables (e.g., extreme heat days, number of warm nights, growing season, heavy precipitation) using two emissions scenarios (low and high) until 2100.

Workshops

Three workshops coordinated by G. Garfin with the city and county of Las Cruces regarding climate change. Las Cruces, NM. November 2015, February 2016, and April 2016.

Other funding: NIDIS – Coping with Drought



PHOTO CREDIT: ERIKA GEIGER, USGS.

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

CLIMAS Investigators: C. Woodhouse and B. Brice

Abstract: The purpose of this project is to investigate Colorado River basin droughts, and the climatic factors that influence those droughts. 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 to determine how warming temperatures may influence river flow and water supply in the future.

Selected Deliverables:

Publication

Woodhouse, C., G. Pederson, K. Morino, S. McAfee, G. McCabe. 2016. Increasing influence of air temperature on upper Colorado River streamflow. *Geophysical Research Letters* 43. DOI:10.1002/2015GL067613.

Information from this publication was reported on by more than 40 news outlets in March and April 2016.

Workshop

Woodhouse, C. Disentangling the Influence of Temperature and Antecedent Soil Moisture on Colorado River Water Resources. U.S. Geological Survey. September 17, 2015.

Presentations

Two presentations by C. Woodhouse regarding the role of temperature and soil moisture in Mediating relationships between cool season precipitation and water year streamflow in the Upper Colorado River Basin. Denver, CO. July 2015.

Five presentations from the research team were given at the Water Manager Advisory Board workshop, Denver Federal Center. Denver, CO. Sept. 17, 2015.

Other funding: U.S. Department of the Interior Southwest Climate Science Center

COMMUNICATING SCIENCE



LAKE MEAD AND HOOVER DAM WATER INTAKE TOWERS, AS SEEN FROM THE ARIZONA SIDE OF HOOVER DAM.

Climate in Context (RISA Book)

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

Abstract: Climate in Context is an edited volume describing the development and implementation of the NOAA RISA program. The book covers scholarly contributions on use-inspired research in five key areas: understanding the context of working with stakeholders and decision makers, understanding risk-based climate applications, supporting the development of knowledge networks, innovating regional climate services, and advancing science policy.

Selected Deliverables:

Publication

Parris, A., G. Garfin, K. Dow, R. Meyer, and S. Close. 2016. *Climate in Context: Science and Society Partnering for Adaptation*. New York: Wiley-Blackwell.

Other funding: NOAA-Climate Program Office



PHOTO CREDIT: MIKE CRIMMINS.



FLASH FLOOD NEAR TUCSON, AZ..

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:

Workshop

Drought Tools Training Workshop. Prescott, AZ. August 2015. The workshop was requested by the Arizona Section of the Society for Range Management, which has an interest in supporting ranchers and range managers with continuing education on drought monitoring tools.

Other funding: 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.

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

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

Abstract: This case study of Nevada, Arizona, and California examines the end-to-end process of decision support and will be conducted within a framework advocated by the National Research Council. This includes assessing FEMA's climate and weather information needs and gaps; co-producing a decision support tool; and measuring impacts, successes, and limitations of the decision-support tool, engagement process, and partnership.

Selected Deliverables:

Publication

Meadow, A., Z. Guido, M. Crimmins, and J. McLeod. 2016. From principles to action: Applying the National Research Council's principles for effective decision support to the Federal Emergency Management Agency's watch office. *Climate Services* 1:12–23. DOI: [10.1016/J.CLISER.2016.02.002](https://doi.org/10.1016/J.CLISER.2016.02.002).

Online Content

Hydroclimate Dashboard: The dashboard is updated with narrative text each month by NWS partners. Z. Guido updates graphics on the dashboard each month. Work is underway to transition the dashboard to be permanently maintained and operated out of the NWS Western Region Headquarters. [HTTP://WWW.CLIMAS.ARIZONA.EDU/CONTENT/FEMA-DASHBOARD-2](http://www.climas.arizona.edu/content/fema-dashboard-2).

Southeast Arizona Agricultural Weather and Climate Working Group

CLIMAS Investigators: M. Crimmins and J. Weiss

Abstract: University of Arizona Cooperative Extension and the National Weather Service-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 as well as conducting applied research and developing new and enhanced decision-support tools. Main activities have included several training and needs assessment workshops, the development and maintenance of a listserv with more than 100 subscribers, and the development of new NWS forecast

information visualizations and interfaces focused on frost and freezing events.

Selected Deliverables:

Online Content

Email listserv: In conjunction with the National Weather Service, climate briefings and graphics on frost/freeze probability are distributed via an email listserv.

Online Tool: This tool uses degree-day data to anticipate damaging freeze events in southeastern Arizona based on the phenological status of tree nut and wine grape crops.

[HTTPS://UACLIMATEEXTENSION.SHINYAPPS.IO/GDDMAPS/](https://uaclimateextension.shinyapps.io/gddmaps/)

Other funding: USDA-Regional Climate Hub; USDA-Agricultural Resource Services; U.S. Geological Survey; NIDIS – Coping with Drought.



HARVESTING WATERMELONS. PHOTO CREDIT: CHRISTINA GREENE.

Western Region Climate Services Southeast Arizona Agricultural Weather and Climate Working Group

CLIMAS Investigators: M. Crimmins and J. Weiss

Abstract: University of Arizona Cooperative Extension and the National Weather Service-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 as well as conducting applied research and developing new and enhanced decision-support tools. Main activities have included several training and needs assessment workshops, the development and maintenance of a listserv with more than 100 subscribers, and the

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Selected Deliverables:

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[HTTPS://UACLIMATEEXTENSION.SHINYAPPS.IO/GDDMAPS/](https://uaclimateextension.shinyapps.io/gddmaps/)

Other funding: USDA-Regional Climate Hub; USDA-Agricultural Resource Services; U.S. Geological Survey; NIDIS – Coping with Drought.



PHOTO CREDIT: DANIEL FERGUSON.

TreeFlow Transition

CLIMAS Investigators: C. Woodhouse, B. Brice, M. Price, and B. McMahan

Abstract: TreeFlow is a comprehensive web resource on tree-ring reconstructions of streamflow and climate for the western U.S., providing access to data for 70 streamflow reconstructions as well as information on data development and applications. While the primary users of streamflow reconstructions are water resource professionals, people in many other sectors and disciplines may find the data useful.

Selected Deliverables:

Online Content

Treeflow website: In June 2015, the updated and revised Treeflow website moved to a Drupal platform. It provides reconstructions of streamflow and other resources.

WWW.TREEFLOW.INFO.

Climate Services Database Development

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

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:

Publication

Meadow, A., E. McNie, J. Berggern, R. Norton, B. McMahan, G. Owen, and L. Rae. 2016. *NOAA Western Region Climate Service Providers Database Development and Preliminary Analysis*.

Online Content

Western Region Climate Service Providers Database: This 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/CLIMATE-SERVICES/](http://WRCC.DRI.EDU/CLIMATE-SERVICES/).

Other funding: NOAA-Western Regional Partnership



PHOENIX, ARIZONA SKYLINE.

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

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.

Selected Deliverables:

Publications

LeRoy, S., G. Garfin, and M. Black 2016. Anticipating cascading effects from climate extremes. *Eos* 97. doi:10.1029/2016EO048971

Garfin, G., S. LeRoy, B. McMahan, M. Black, and B. Roh. 2016. *Preparing for High-Consequence, Low-Probability Events: Heat, Water & Energy in the Southwest*. Report to the U.S. Bureau of Reclamation from the project, Enhancing Water Supply Reliability. The University of Arizona.

Workshop

Preparing for High-Consequence, Low-Probability Events: Heat, Water & Energy in the Southwest. The University of Arizona, September 28-29, 2015.

Other funding: U.S. Bureau of Reclamation.

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 A. Masayeva

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. The integrated suite of indicators and processes to support monitoring them will provide the foundation for revisions to the Hopi Tribe's current drought management and response plan; result in a new stream of locally derived data and information that could provide input to national drought products like the U.S. Drought Monitor; and be the backbone of a system that would provide local, regional, and national decision makers better insight into developing drought conditions before an event reaches critical levels.

Selected Deliverables:

Publications

Ferguson, D., A. Masayeva, A. Meadow, and M. Crimmins. 2016. Rain gauges to range conditions: Collaborative development of a drought information system to support local decision-making. *Weather, Climate and Society*. Early online release. [HTTP://DX.DOI.ORG/10.1175/WCAS-D-15-0060.1](http://dx.doi.org/10.1175/WCAS-D-15-0060.1).

A drought information system was developed that is based on Hopi citizens' and resource managers' experiences with drought; incorporates local observations of drought impacts and conventional indicators; and brings together local expertise with conventional science-based observations.

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

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 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.

Selected Deliverables:

Publication

Duval, D., A. Kerna, G. Ruyle, L. Howry, and G. Frisvold. (In press). *Economic Impact of Cooperative Extension Efforts in Rangeland Management for Northern Arizona Ranching Allotment*. Working Paper. Arizona Cooperative Extension.

Evaluates the economic benefits of rangeland management extension to help ranchers maintain herd size in the face of drought.

Presentations

Three presentations by G. Frisvold on cotton acreage abandonment: The Role of Economics, Climate, and Policies. New Orleans, LA (January 2016); Champaign-Urbana, IL (April 2016); Tucson, AZ (May 2016).

Other funding: NIDIS – Coping with Drought.

ECONOMICS & LIVELIHOODS



COTTON PLANT. PHOTO CREDIT: JUD MCCRANIE.

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 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.

Deliverables:

Publications

Frisvold, G. 2015. *Developing Sustainability Metrics for Water Use in Arizona Small Grain Production*. Final Report to the Arizona Grain Research and Promotion Council. Phoenix, AZ: Arizona Department of Agriculture.

Using better data to develop more accurate estimates, researchers found that Arizona durum wheat production has a water footprint that is smaller than many other durum production regions.

Study results reported by KJZZ (the Phoenix National Public Radio affiliate), *AgWeek*, U.S. Wheat Associates, *Wheat Letter*, and *Rediscover Wheat* (Kansas Association of Wheat Growers and the Kansas Wheat Commission).

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://WWW.COTTON.ORG/BELTWISE/INDEX.CFM?PAGE=PROCEEDINGS](https://www.cotton.org/beltwide/index.cfm?page=proceedings).

The USDA Office of the Chief Economist, the Arizona Agribusiness and Water Council, and the Arizona Cotton Growers Association requested information from this report.

Frisvold, G. 2015. Water, Agriculture, and Drought in the West Under Changing Climate and Policy Regimes. *Natural Resources Journal* 55:293-328.

Presentations

Three presentations by G. Frisvold regarding agriculture in Yuma, AZ. Yuma, AZ (January 2016); Tucson, AZ (March 2016); Yuma, AZ (May 2016).

Invited Testimony

G. Frisvold was invited to testify before the U.S. House of Representatives Committee on Natural Resources Subcommittee on Federal Lands. Exploring Current Natural Resource Research Efforts and the Future of America's Land-Grant Colleges and Universities. April 20, 2016.

[HTTP://DEMOCRATS-NATURALRESOURCES.HOUSE.GOV/IMO/MEDIA/DOC/TESTIMONY_BURGESS1.PDF](http://democrats-naturalresources.house.gov/imo/media/doc/testimony_burgess1.pdf).

Other funding: NIDIS – Coping with Drought.



COTTON FIELD, LATE IN SEASON. PHOTO CREDIT: JUD MCCRANIE.



SOLAR PANELS OF ROOF OF BUSINESS.

Arizona Business Resilience Initiative – An Initiative To Support Arizona’s Business Community In Managing Climate Risk

CLIMAS Investigators: B. McMahan, M. Crimmins, D. Ferguson, and 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 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?

Selected Deliverables:

Data Outputs

Qualitative Assessments: Four assessments including Heat/Climate, Water Availability, Wildfire Risk, and Air Quality Concerns. Assessments co-produced with Tucson Electric Power (TEP) based on their needs. Growing evidence that the utility is using this information in revising their strategic resource plans.

Data Visualization and Analysis Tools: These tools allow TEP to integrate spatial concerns about infrastructure risk and resource distribution into ongoing planning activities.

Workshop

McMahan, B. Planning for Cascading Effects. Tucson AZ, March 22, 2016.

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

EDUCATION AND TRAINING



DAN FERGUSON DOING FEILDWORK WITH CLIMATE AND SOCIETY FELLOW CHRIS GUITERMAN. PHOTO CREDIT: CHRIS GUITERMAN

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

CLIMAS Investigators: C. Woodhouse and D. Ferguson

Abstract: 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.

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

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

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

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:

Publication

Brown, H., M. Roach, G. Smith, M. Wilder, S. Chambers, I. Patten, and Q. Rabby. 2016. *Assessment of Climate and Health Impacts on Vector-Borne Diseases and Valley Fever in Arizona*. Report to Arizona Department of Health Services.

Summary of expected infectious disease outcomes due to climate in Arizona with a vulnerability assessment performed at the census block level.

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



DUST DEVIL. PHOTO CREDIT: DAVID DUBOIS.



HABOOB. PHOTO CREDIT: 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. In 2105, the construction of a synoptic climatology of the dust storms began to increase the ability to forecast these events. Through this project, the New Mexico Department of Transportation (DOT) has increased its interest in public safety and mitigation of dust. The DOT staff has since requested and obtained federal funding for mitigation and public notification projects.

Selected Deliverables:

Publications

Kavouras, I., D. DuBois, G. Nikolich, A. Corral Avittia, and V. Etyemezian. 2015. Particulate dust emission factors from unpaved roads in the U.S.-Mexico border semi-arid region. *Journal of Arid Environments* 124:189-192. [HTTP://DX.DOI.ORG/10.1016/J.JARIDENV.2015.07.015](http://dx.doi.org/10.1016/j.jaridenv.2015.07.015).

Provides site-specific PM10 emission rates of unpaved roads in areas that have been deemed problematic by local authorities and the public.

Armenta, R. 2016. *Geopotential Height Patterns at 500mb Associated with Major Dust Storms in the United States/Mexico Border Region During January-May of 2011-2014*. Master's thesis. New Mexico State University.

Develops a method for calculating a mean dust-day 500mb height map that can be used to forecast synoptic scale dust storms over the U.S./Mexico border region.

Workshop

New Mexico Dust Storm Stakeholder meeting. Collaboration with the New Mexico DOT. February 24, 2016. This workshop improved the understanding of dust storms and dust-related crashes; developed an interagency coalition to reduce dust storm crashes, injuries, and fatalities; and introduced new driver safety and dust mitigation projects.

Other funding: New Mexico Department of Health; NIDIS – Coping with Drought.



PHOTO CREDIT: BOB DUSEK, USGS.

Climate and Health

CLIMAS Investigators: A. Comrie and H. Brown

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:

Publication

Brown, H., A. Young, J. Lega, T. Andreadis, J. Schurich, and A. Comrie. 2015. Projection of climate change influences on U.S. West Nile virus vectors. *Earth Interactions* 19:1-18. DOI: [HTTP://DX.DOI.ORG/10.1175/EI-D-15-0008.1](http://dx.doi.org/10.1175/EI-D-15-0008.1).



PHOTO CREDIT: BHUWAN THAPA.

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SAGUARO DETAIL (CAVECREEK, AZ.).



THUNDERSTORM, CARRIZOSO, NM. PHOTO CREDIT: DAVID DUBOIS.

