



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

**The Climate Assessment
for the Southwest (CLIMAS)**

2013-14

ANNUAL PROGRESS REPORT



Contents

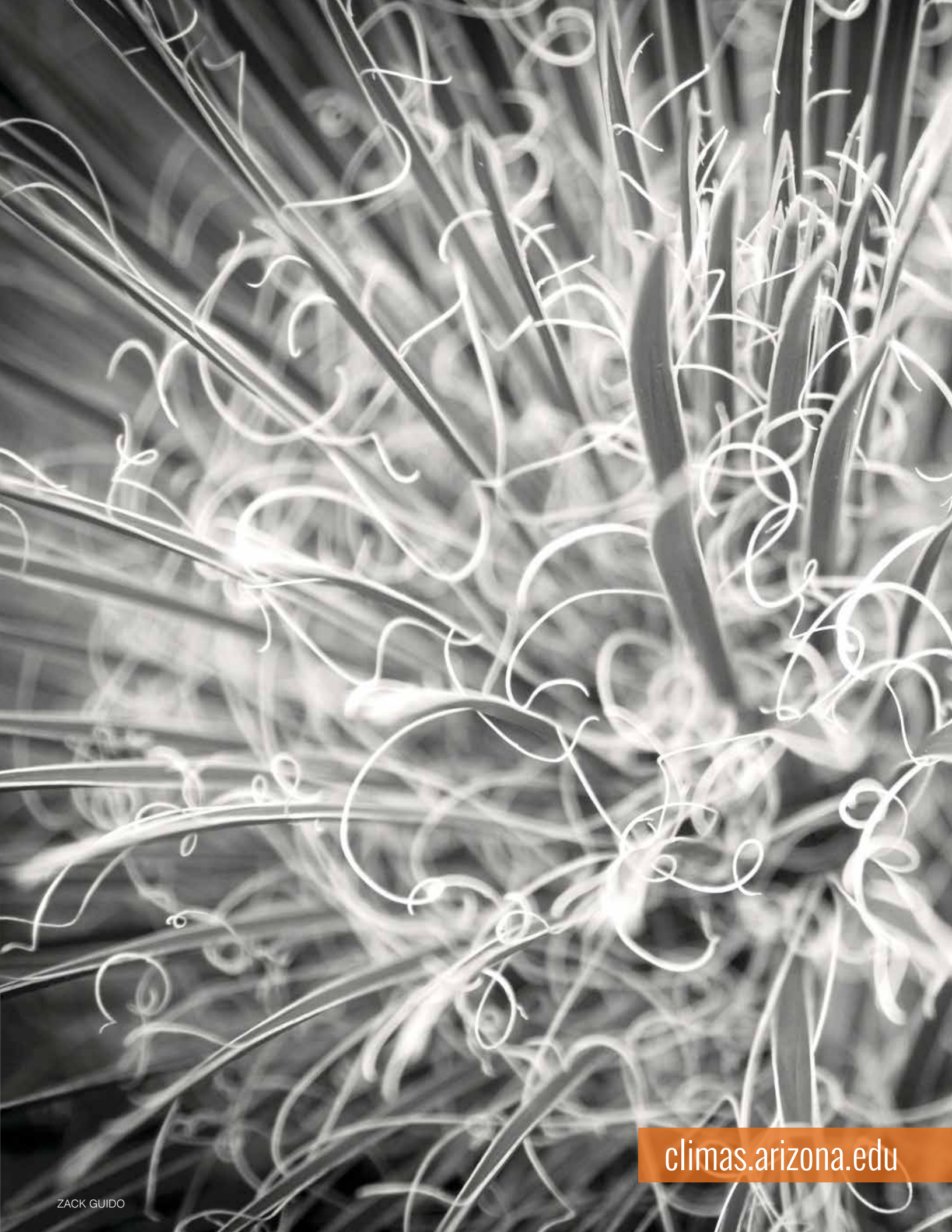
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RISA

A REGIONAL APPROACH TO CLIMATE SERVICES: REGIONALLY INTEGRATED SCIENCES AND ASSESSMENTS (RISA)

In the mid-1990s, the National Oceanic and Atmospheric Administration (NOAA) created the Regional Integrated Sciences and Assessments (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 June 2014, 11 RISA teams are funded, covering much of the United States and U.S. territories in the Pacific.



Climate Assessment for the Southwest (CLIMAS)

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

The primary focus of the program is Arizona and New Mexico, although members of the CLIMAS team conduct research around the world. Headquartered at the University of Arizona's Institute of the Environment, CLIMAS also includes a core group of investigators at New Mexico State University as well as affiliated researchers throughout the West. The CLIMAS mission is to improve the region's ability to respond sufficiently and appropriately to climatic events and changes. The program promotes participatory, iterative research involving scientists, decision makers, resource managers, educators, and others who need more and better information about climate and its impacts. CLIMAS investigators conduct research about the nature, causes, and consequences of climate change and variability in the southwestern United States, providing valuable information to decision makers in a variety of fields, including water and fire management, agriculture, ranching, and public health. The program also supports efforts to improve climate forecasting in the region. Since its establishment more than 15 years ago, CLIMAS has built a large, diverse network of stakeholders and partners who have worked together on a tremendous range of projects. This report highlights some of the work in which CLIMAS was engaged from May 2013 through May 2014.

CLIMAS Team

PRINCIPLE INVESTIGATORS

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ZACK GUIDO

CLIMAS by the Numbers 2013-14

Outputs



Stakeholders & Partners

GOVERNMENT



NON-GOVERNMENT



2012-14 Climate Impacts & Events in the Southwest

DROUGHT ON JUNE 18

Drought conditions were widespread and intense across the Southwest. Severe and extreme drought covered 72 and 22 percent of Arizona, and 99 and 90 percent of New Mexico, respectively.

DROUGHT ON OCTOBER 1

Drought conditions substantially improved in both states as a result of monsoon precipitation. Severe drought covered only 25 percent of Arizona; the state had no extreme drought. Severe and extreme drought covered only 38 and 3 percent of New Mexico, respectively.

MAY JUN JUL AUG SEP OCT NOV DEC

2012

MONSOON, JULY 1 – SEPT 15

The monsoon drenched many rural parts of Arizona and New Mexico but dodged the metropolitan cities of Arizona. Overall, the Southwest received above-average precipitation, with near-record amounts falling in Douglass and Flagstaff, Arizona.

Sectors in which CLIMAS worked:



WINTER PRECIPITATION

November 1, 2013 – April 1, 2014

For a fourth consecutive winter, below-average precipitation fell in the Southwest. Arizona and New Mexico logged their ninth and third driest January–March periods since 1895, respectively.

WINTER TEMPERATURE RECORDS

The January–March period in Arizona was the warmest since record-keeping began in 1895. The persistent high-pressure system over California prevented colder, northern storms from drifting through the region, contributing to mild winter temperatures.

MAJOR RESERVOIRS STORAGE APRIL 30

Between April 30, 2013, and April 30, 2014, combined storage in Lakes Mead and Powell in Arizona declined by about 3.5 million acre-feet. In New Mexico, Elephant Butte Reservoir was only 17 percent full and farmers in the Elephant Butte Irrigation District braced for substantially reduced water allotments.

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

2013

2014

WILDLAND FIRES RAGE IN 2013

About 105,000 acres in Arizona and about 222,000 acres in New Mexico burned in 2013. The median number of acres burned between 1990 and 2010 is about 129,000 in Arizona and 146,000 in New Mexico.

ANOTHER ENSO-NEUTRAL WINTER

For the second consecutive winter, sea surface temperatures in the tropical Pacific Ocean were near average, reflecting an ENSO-neutral event. Neutral events tip the scales slightly in favor of dry winter conditions in the Southwest.

DROUGHT ON APRIL 1

A dry and warm winter caused drought conditions to expand and intensify in the Southwest. Severe, extreme, or exceptional drought covered 88 percent of Arizona on April 1, 2014, compared to 62 percent on November 5, 2013. In New Mexico, severe drought during that same period expanded from 74 to 98 percent.

A RIDICULOUSLY RESILIENT RIDGE OF HIGH PRESSURE

A high pressure system parked off the California coast for much of the winter, preventing soppy winter storms from wafting into the Southwest. This ridge contributed to historically dry conditions in California and led to a state disaster declaration. Some preliminary estimates suggest the drought cost California \$1.7 billion and left 14,500 farmworkers without jobs.

EL NIÑO WATCH

In April, signs began pointing to the formation of an El Niño event, with early indications suggesting a moderate or strong event. El Niño events tend to deliver wet conditions to Arizona and New Mexico during the winter.

Highlights: Research Activities, Collaborations, & Findings

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

Lead CLIMAS Investigator: Michael Crimmins

A co-designed (FEMA, CLIMAS, NWS) custom climate information system for FEMA led to the development of a “dashboard” of flood risk information, including the creation of flood impact and precipitation climatologies. This experimental dashboard will be handed off to the Western Region Headquarters of the National Weather Service.

Air Quality and Climate

Lead CLIMAS Investigator: David DuBois

Regional fire incidents and windblown dust events may trigger high ozone episodes that exceed air quality standards. Data suggests that higher levels of particulate material (PM10 and PM2.5) and ozone in the air during April to September caused increased emergency room (ER) admissions during these months. Cardiovascular-related ER visits increased by 3.1 percent during periods of high PM10 levels and by 2.8 percent for high PM10-2.5 levels. Wildfire and dust sources within 500 kilometers of the study area accounted for most of the particle mass and ozone concentrations.

Sectoral Impacts of Drought and Climate Change

Lead CLIMAS Investigator: George Frisvold

Presentation to the Arizona House of Representatives, Committee on Agriculture and Water. *The Contribution of Agriculture to the Yuma Economy*. February 2014, Yuma, AZ.

While agricultural-urban or agricultural-environmental water transfers have been identified as a key means to adapt to drought and climate change, there is concern in rural communities about the economic impacts of such “water exports.” This presentation first discussed how to measure agriculture’s contribution to a local economy. It then considered economic impacts of reduced water supplies to agriculture. This was an invited presentation by state, county, and city officials and business leaders, and has resulted in requests for further information and analysis (Agri-Business Council of Arizona, Arizona Farm Bureau, Office of Governor Jan Brewer, AZ).

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

Lead CLIMAS Investigator: Daniel Ferguson

With the Hopi Department of Natural Resources (HDNR), this research team co-developed an experimental quarterly Hopi Drought Summary report. This product synthesizes various data sources that reflect ongoing drought status on Hopi lands. The first issue was released in early April 2014. The drought summary was explicitly designed to provide the HDNR with a status update on drought conditions and demonstrate to HDNR technicians how the data they collect may be used.

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

Lead CLIMAS Investigator: Gregg Garfin

The projected five-model weighted average streamflow for the Gila River at Gila is a 6 percent decrease in water quantity (with a 15 percent decrease in the median streamflow); for the Gila at Virden it is an 8 percent decrease (15 percent median decrease); and for the San Francisco River at Clifton it is an 11 percent decrease (19 percent median decrease) for the time period 2041–2070 in comparison to the time period 1971–2000. Low flows are projected to get even lower in the future, and very high flows are expected to get even higher, even as overall streamflow is projected to decrease.

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

Lead CLIMAS Investigator: George Frisvold

Several commentators have suggested that adoption of improved irrigation will be important for agricultural adaptation to climate change in the western United States. Regression results, however, suggest that smaller-scale producers adopt more efficient sprinkler irrigation systems to a significantly lower extent than their larger-scale counterparts. Even among larger operations, adoption of sprinkler irrigation may not be a preferred adaptation to climate warming. Results suggest that sprinkler irrigation is a more likely climate change adaptation in areas that are relatively cold and where extreme precipitation events increase.

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

Lead CLIMAS Investigator: Michael Crimmins

Indices that capture regional hydroclimatic extremes (e.g., dry spell length and number of rain days) lend unique and important insight into the multiple pathways that drought conditions can develop. This insight can inform more locally relevant drought monitoring techniques.

Adaptation Strategies for Water and Energy Sectors in the Southwest

Lead CLIMAS Investigator: Bonnie Colby

More flexible water trading arrangements across water users within watersheds can substantially reduce the economic impact of drought. Electric utilities need to consider the best ways to meet higher peak loads for cooling during the summer months in the Southwest under climate change.

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

Lead CLIMAS Investigator: Margaret Wilder

In the City of Tucson, citizens' water advisory boards can increase the institutional adaptive capacity of a local water utility. Although the advisory boards do not specifically address climate change, they advise elected officials on matters pertaining to water resources adaptation. Indicators of adaptive capacity such as fair governance, legitimacy, and social learning were, generally speaking, enhanced by the existence of the Citizens' Water Advisory Council, while other relevant aspects of water governance (e.g., conflicting goals, politics) were not adequately captured by the adaptive capacity analysis.

CLIMAS Contributions to the National Climate Assessment

CLIMAS Investigators: G. Garfin, K. Jacobs, A. Comrie, M. Crimmins, D. Ferguson, G. Frisvold, J. Overpeck, M. Wilder, J. Galayda, C. Greene, and D. Liverman

The National Climate Assessment was released on May 6, 2014. The Southwest chapter (Chapter 20) documents critical climate change impacts to the region's coasts and forests, and projects increased risks to water resources reliability, agriculture, and public health. The chapter notes the special vulnerabilities of native nations and U.S.-Mexico border cities due to high rates of poverty and low tax bases for generating resources needed to develop and improve roads, water treatment and distribution, and other infrastructure. The chapter also points to adaptive responses by state and local governments, water utilities, forest managers, and federal agencies to reduce the impacts of current and future changes. The chapter gives an example of how the region can reduce its production of heat-trapping greenhouse gases through the adjustment of energy sources used in the generation of electricity while also reducing water use. See <http://nca2014.globalchange.gov/report/regions/southwest>.



Publication:

Garfin, G., G. Franco, H. Blanco, A. Comrie, P. Gonzalez, T. Piechota, R. Smyth, and R. Waskom. 2014. Ch. 20: Southwest. *Climate Change Impacts in the United States: The Third National Climate Assessment*, J. Melillo, T. Richmond, and G. Yohe (eds.). U.S. Global Change Research Program, 462-486. doi:10.7930/J08G8HMN.

Presentations:

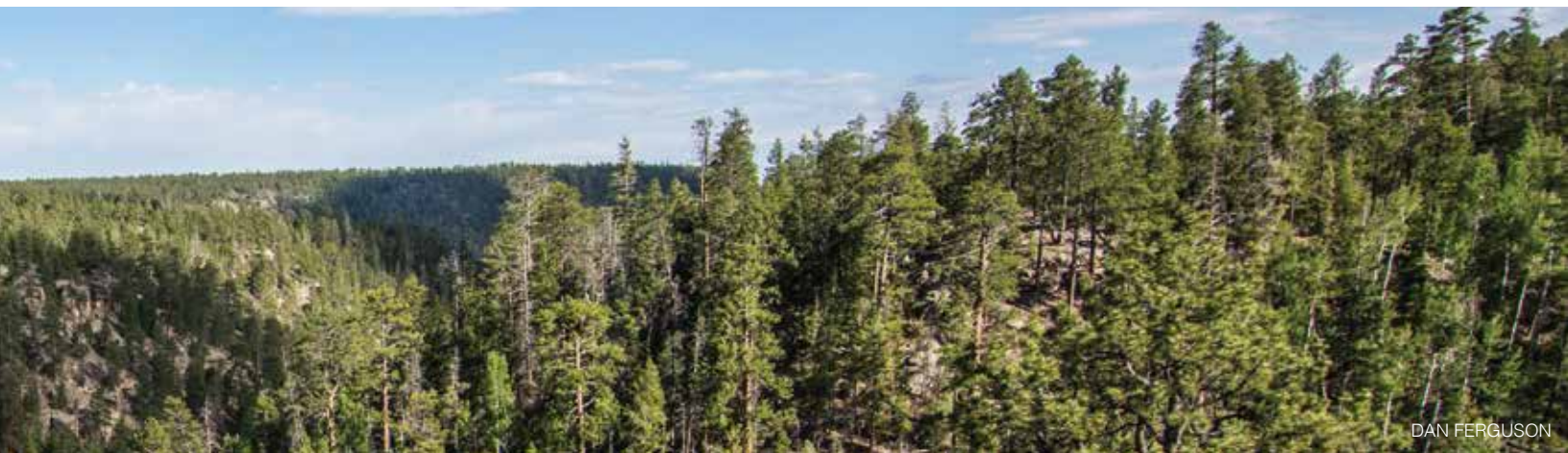
- (1) Projected Climate Changes for the United States: Key Findings. Continuing Legal Education. August 2013, Reno, NV.
- (2) Partnerships for Managing Risk. National Council on Science and the Environment Annual Conference. January 2014, Arlington, VA.
- (3) Projections of Climate and Water-Related Variables for the Southwest. U.S. Arizona Hydrological Society. February 2014, Tucson, AZ.
- (4) National Climate Assessment Insights for the Southwest. American Water Works Association Sustainable Water Management Conference. April 2014, Denver, CO.
- (5) Third National Climate Assessment: Climate Change Impacts in the United States. National Climate Assessment Panel Discussion. May 2014, Tucson, AZ.
- (6) Climate Change Resources. Southwest Climate Science Center Workshop Integrating Climate Science into Management Decision Making: Challenges and Opportunities. May 2014, Tucson, AZ.
- (7) Southwest. Union of Concerned Scientists NCA Webinar Series. May 2014, Virtual.

Media coverage after the release of the May 2014 National Climate Assessment:

- (1) Banerjee, N. and K. Hennessey. 2014. Climate change assessment paints stark picture of potential damage. *Los Angeles Times*. May 6. <http://www.latimes.com/nation/la-na-climate-change-assessment-20140505-story.html>
- (2) Davis, T. 2014. Report: Southwest faces increased threat from drought, wildfires and heat. *Arizona Daily Star*. May 6. http://azstarnet.com/news/science/report-southwest-faces-increased-threat-from-drought-wildfires-and-heat/article_4314256a-d540-11e3-87b3-001a4bcf887a.html
- (3) Davis, T. 2014. Climate change hitting home, says White House report led by UA. *Arizona Daily Star*. May 7. http://azstarnet.com/news/local/education/college/climate-change-hitting-home-says-white-house-report-led-by/article_9b4e7d25-338b-5ee5-ab54-4f705bca5d20.html
- (4) Doug McIntyre Show - KABC Radio, Los Angeles, CA. May 8.
- (5) Fleck, J. 2014. Report: NM to be hotter, drier. *Albuquerque Journal*. May 7. <http://www.abqjournal.com/395501/news/nm-drier-hot-under-climate-change.html>
- (6) Loomis, B. 2014. Worse drought, wildfires forecast for the Southwest. *The Republic*. May 6. <http://www.azcentral.com/story/weather/2014/05/07/worse-drought-wildfires-forecast-southwest/8796155/>
- (7) The Story Group. 2014. *National Climate Assessment: Southwest Chapter Video*. <http://vimeo.com/92687378>

Assessment of Climate Change in the Southwest United States: a Technical Report Prepared for the U.S. National Climate Assessment

The Southwest Chapter for the National Climate Assessment was based on *The Assessment of Climate Change in the Southwest United States*, a technical input report published in May 2013. The technical input report is a summary and synthesis of the past, present, and projected future of the region's climate, examining what this means for the health and well-being of human populations and the environment throughout the six southwestern states—Arizona, California, Colorado, Nevada, New Mexico, and Utah—that collectively encompasses vast stretches of coastline, an international border, and the jurisdictions of more than 100 Native nations. This year, results from this report were distributed through presentations, publications, and media coverage throughout the Southwest.



DAN FERGUSON

Publications:

- (1) Garfin, G., A. Jardine, R. Merideth, M. Black, and S. LeRoy (eds.). 2013. *Assessment of Climate Change in the Southwest United States: A Report Prepared for the National Climate Assessment*. Washington, DC: Island Press. <http://swccar.org/sites/all/themes/files/SW-NCA-color-FINALweb.pdf>
- (2) Fact Sheets for Chapters 3-20. In *Assessment of Climate Change in the Southwest United States: A Report Prepared for the National Climate Assessment*, G. Garfin, A. Jardine, R. Merideth, M. Black, and S. LeRoy (eds.). Washington, DC: Island Press. <http://www.swcarr.arizona.edu/key-findings>
- (3) Garfin, G. 2013. Assessment of climate change in the Southwest United States: Key findings. *5th Annual Science on the Sonoita Plain Symposium*. June 8, 2013. Elgin, AZ: Cienegas Watershed Partnership, p. 5-7.

Presentations:

Thirty-four presentations regarding findings of the Southwest Climate Assessment were given between May 2013 and May 2014.

Other Funding Sources: U.S. Global Climate Research Program; National Aeronautics and Space Administration; U.S. Geological Survey

Media articles based on the Southwest

Technical Input Report:

- (1) Liverman, D. and G. Garfin. 2013. A Warning from the American Southwest: It's Getting Hotter. *The Washington Spectator* 39(10):1-4. October 1. <http://www.washingtonspectator.org/index.php/Environment/a-warning-from-the-american-southwest-its-getting-hotter.html#.UmBgmFCsiM5>
- (2) Falk, D. and G. Garfin. 2013. Guest Column: There's no doubt: Earth is warming, and it's our fault. *Arizona Daily Star*. September 29.
- (3) Garfin, G. 2013. Guest Column: How would an extra month of 100-plus degree days feel? *Arizona Daily Star*. May 1. http://azstarnet.com/news/opinion/guest-column-how-would-an-extra-month-of-plus/article_54978a1f-dc1f-5ec6-afdd-6e8b3c790c26.html

CLIMAS Projects Started 2013-14

1 Southwest Climate Podcasts

CLIMAS Investigators: Z. Guido, M. Crimmins, R. Thomas, and J. Dollin

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. The podcasts synthesize information from disparate sources, translating the national and global discussions for the Southwest. The podcasts also bring in the latest climate science, delivering nuanced discussions about climate-related topics while avoiding technical jargon.

2 Climate and Society Graduate Fellows Program

CLIMAS Investigators: G. Owen, D. Ferguson, Z. Guido, R. Thomas, R. Lybrand, L. Huang, C. Guiterman, and S. Truebe

The Climate and Society Graduate Fellows Program provides support for currently enrolled University of Arizona graduate students from any degree-granting program whose work is focused on the nexus of climate research and decision making. Up to four fellowships of \$5,000 each are awarded annually, leveraged with funds from the Office of the Vice President for Research at the University of Arizona.

Current 2014 Fellows will present results from their research projects, described below, at a CLIMAS-sponsored symposium in November 2014.

- *Rebecca Lybrand* is creating two short films that integrate results from her dissertation on how soil carbon cycling changes with shifting climates in the Southwest.
- *Ling-Yee Huang* is developing an integrated climate science and climate law curriculum to expose law students to the process and methods of climate science and climate change litigation that relies on this information.
- *Chris Guiterman* is working with Navajo Forestry Department foresters to quantify the climatic drivers of forest growth in the Chuska Mountains in New Mexico.
- *Sarah Truebe* is working with scientists and cave managers to develop current best-practice guidelines for sampling speleothems, which are archives of paleoclimate information.



DAN FERGUSON



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

CLIMAS Investigators: C. Woodhouse and B. Brice

Research Partners: U.S. Geological Survey - Bozeman, MT and Denver, CO; Alaska Climate Science Center; Desert Research Institute; University of Nevada - Department of Geography

The main goal of this project is to better understand how the set of hydroclimatic factors—prior summer/fall soil moisture, cool season precipitation/snowpack, and late winter/spring temperatures—contribute to low annual flows on the Colorado River. We will use a combination of instrumental data, tree-ring reconstructions, and downscaled CMIP5 projections to investigate the differing roles of these factors in both instrumental period droughts and droughts that have occurred over past centuries, including conditions in major sub-basins. We will test the sensitivity of annual low flows to different CMIP5 scenarios of changes in soil moisture, winter precipitation, and winter/spring temperatures, and compare climate conditions associated with historic/paleo low flows to those associated with low flows derived from downscaled projections. This is a Department of the Interior Southwest Climate Science Center project with leverage from CLIMAS.

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

CLIMAS Investigators: G. Garfin and M. Hammersley

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

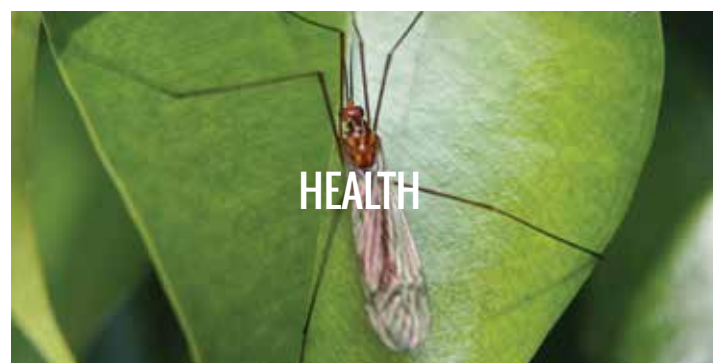
5 Developing and Leading a Climate and Health Research Network on the University of Arizona Campus

CLIMAS Investigators: M. Wilder, H. Brown, J. Overpeck, D. Ferguson, and E. Lawlor

During 2013–14, Wilder and Brown initiated a climate-health research nexus for interdisciplinary research on these topics at the University of Arizona. The goals of this initiative are to foster a community of interdisciplinary researchers working at the intersection of climate and health and develop core concepts for fruitful collaboration on externally funded grant proposals.

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:



Adaptation & Vulnerability

Adaptation Strategies for Water and Energy Sectors in the Southwest

CLIMAS Investigators: B. Colby, G. Frisvold, B. Fleck, R. Klawitter, D. Duval, and A. Clarke

Research Collaborators: E. Basta, E. Schuster, and A. Kerna (Univ. of Arizona - Department of Agricultural Resources and Economics); U.S. Bureau of Reclamation; U.S. Department of Agriculture; Sonoran Institute; New Mexico Office of the State Engineer; and The Nature Conservancy

Partners: Arizona Department of Water Resources; Central Arizona Project; Salt River Project; Western Resource Advocates; Environmental Defense; ProNatura; Western Governors Association; Western States Water Council; and National Audubon Society

ABSTRACT

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



DELIVERABLES

(1) Publications:

Colby, B., G. Frisvold, and M. Mealy. 2014. Reallocating Climate Risks through Water Trading. In *Routledge Handbook of Water Economics and Institutions*, K. Burnett, R. Howitt, J. Roumasset, and C. Wada (eds.). New York: Routledge. (In press). More flexible water trading arrangements provide an effective means to reduce the economic impact of drought.

Colby, B. 2014. Innovative Water Transactions to Meet Urban and Environmental Demands in the Face of Climate Change. In *Innovations in Water Markets*, W. Easter (ed.). New York: Springer. (In press). Changing regional hydrology and temperatures provide impetus for new contractual agreements to provide more reliable water supplies for urban and environmental needs.

Schuster, E. and B. Colby. 2013. Farm and ecological resilience to water supply variability. *Journal of Contemporary Water Research and Education* 151(1):70-83. Farmers in northwestern Mexico are adapting to water supply variability by investing in technology and changing their crop mix and acreage planted.

(2) Presentations:

Water Banks: Protecting Colorado's Economy from Drought Impacts. Water Resources Review Committee, Colorado Legislative Hearing. October 2013, Denver, CO.

Valuing Colorado's Agricultural Water Use: Recommendations for Water Policymakers. October 2013, Colorado Springs, CO.

Trading Risk, Water, and Money: Refining Water Markets. Bren School Water Policy Colloquium. November 2013, Santa Barbara, CA.

Other Funding Sources:

University of Arizona - Office of Arid Lands Studies; U.S. Bureau of Reclamation; Walton Family Foundation; Sonoran Institute; NOAA Sectoral Applications Research Program; NOAA Regional Climate Centers

Assessing Regional Climate Service Needs through Cooperative Extension

CLIMAS Investigators: M. Crimmins, D. DuBois, and J. Brugger
Research Collaborators: University of Arizona – Cooperative Extension

ABSTRACT

Cooperative Extension (CE) has more than 100 years of experience in delivering science-based decision support to clientele from multiple sectors. The CE structure enables a high level of connectedness and awareness of local issues and provides opportunities to assess local and multi-sector climate service needs. This research used CE offices to capture snapshots of local climate science and service needs across rural areas of Arizona and New Mexico. Since CE agents in these states work closely with both private land owners/producers (e.g., ranchers and farmers) and state/federal natural resource managers, researchers assessed both the needs and interconnections between private and public resource managers, consistent with the “nested matrix” concept of assessing climate change impacts and responses at multiple scales.

DELIVERABLES

(1) Publications:

Brugger, J. and M. Crimmins. 2013. The art of adaptation: Living with climate change in the rural American Southwest. *Global Environmental Change* 23(6):1830-1840. <http://dx.doi.org/10.1016/j.gloenvcha.2013.07.012>

Brugger, J. and M. Crimmins. 2014. Designing institutions to support local level climate change adaptation: Insights from a case study of the US Cooperative Extension System. *Weather, Climate and Society*. (In press).

Other Funding Sources:

USGCRP National Climate Assessment

DELIVERABLES

(1) Publication:

Proceedings of the 5th Annual Science on the Sonoita Plains, June 8, 2013. Quarterly Meeting of the Sonoita Valley Planning Partnership and the Cienega Watershed Partnership. <http://researchranch.audubon.org/PDFs/Science%20on%20the%20Sonoita%20Plain%202013%20Symposium.pdf>. Sections included in the proceedings constitute a summary of the project, including a background describing scenario planning, the CLIMAS climate scenarios used in this project, and the narratives for each of the resource groups.

(2) Workshop:

University of Arizona, Tucson, AZ. April 10, 2013. Project participants divided into four resource groups—montane, upland, riparian, and cultural—and worked towards developing their respective scenario narratives. This workshop enabled participants to systematically build their scenario narratives. Individual group meetings were subsequently arranged, usually webinar-style, to assist each group.

(3) Newsletter distribution:

Three newsletters were distributed to middle and upper management personnel across the various state and federal organizations that were involved in this project to keep them apprised of our progress.

Scenario Planning in the Cienegas Watershed

CLIMAS Investigator: K. Morino

Research Collaborators: H. Hartmann (Univ. of Arizona – School of Natural Resources and the Environment); U.S. Bureau of Land Management; The Nature Conservancy; and Cienega Watershed Partnership

Partners: Cienegas Watershed Partnership – U.S. Bureau of Land Management, Tucson Field Office; U.S. Fish & Wildlife Service; National Park Service - Saguaro National Park; U.S. Department of Agriculture – Agricultural Research Service, Natural Resources Conservation Service; Pima Association of Governments; Cuenca Los Ojos Foundation; Pima County; U.S. Forest Service - Coronado National Forest; Audubon Appleton-Whittell Research Ranch; Sky Island Alliance; Southwest Decision Resources; and The Nature Conservancy

ABSTRACT

Resource managers face major challenges in developing medium- and long-term management plans considering the uncertainty arising from various climatic and socioeconomic factors. One approach to circumventing what can be a paralyzing level of uncertainty is scenario planning. This approach allows managers to “embrace uncertainty” and strategically prepare for a wide range of possible futures. This project demonstrated a collaboration with the Cienegas Watershed Partnership to develop a set of scenario narratives, with specific scenario sets for each of four resource areas: montane, upland, riparian, and cultural. Participants were challenged to consider uncertainties and potential changes in climate, social, technological, economic, environmental, and political forces that are beyond the control of the Cienegas Watershed Partnership. Under the auspices of scenario planning, each resource group was able to consider and discuss future sets of conditions and management challenges that generally do not get a lot of attention.

Other Funding Sources: The Nature Conservancy

Climate Change Analysis for the City of Tucson

CLIMAS Investigators: G. Garfin, G. Frisvold, A. Comrie, B. Colby, and J. Weiss

Research Collaborators: Cascadia Consulting Group; T. Kong and D. Garcia (Univ. of Arizona - School of Natural Resources and the Environment); and C. Carrillo (Univ. of Arizona – Atmospheric Sciences)

Partners: City of Tucson; City of Tucson - Office of Conservation and Sustainable Development; and City of Tucson - Climate Change Committee

ABSTRACT

This project involved conducting a vulnerability assessment for the City of Tucson and its contractors regarding anticipated climate change impacts. Project goals included conducting studies and delivering best estimates on projections of future climate and hydrology of the Tucson Basin and projections of future climate and hydrology of Colorado River surface water supplies that are part of Tucson Water’s water resources portfolio. Researchers synthesized state-of-the-art research related to Tucson energy-water nexus issues, Tucson’s urban heat island, risk related to selected diseases, local food security, and projected impacts and risks related to urban ecosystems and ecosystems surrounding the city. Researchers synthesized studies on vulnerability assessment and adaptation-related economic research pertaining to Tucson and southern Arizona.

DELIVERABLES

(1) Decision Support: Temperature and precipitation projections for the City of Tucson, 1950–2099. Maps of extreme temperature risk, flood risk, and combinations of flood risk and socioeconomic status and extreme temperature risk and socioeconomic status. The projections and maps aid the City of Tucson Office of Sustainable Development and the City’s Climate Change Committee in anticipating and planning for future risk.

Other Funding Sources: City of Tucson



ZACK GUIDO

DELIVERABLES

(1) Publication:

Frisvold, G. and S. Deva. 2013. Climate and choice of irrigation technology: implications for climate adaptation.

Journal of Natural Resources Policy Research 5(2-3):107-127. Across 17 western states, adoption of sprinkler irrigation is a more likely climate change adaptation in areas that are relatively cold and where extreme precipitation events increase.

Other Funding Sources:

U.S. Department of Agriculture - Economic Research Service

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

CLIMAS Investigators: G. Frisvold, K. Emerick, A. Murugesan, and T. Bai

Research Collaborators: U.S. Bureau of Reclamation and Central Arizona Project

ABSTRACT

This project examines mechanisms for adapting to climate variability and change that include (1) the use of water markets by agriculture and urban water utilities, (2) the use of weather and climate information by agricultural producers, (3) the adoption of improved irrigation technologies, and (4) agricultural and other policy responses. The articles published as part of this project (Frisvold and Deva 2012, 2013) highlighted the value of special cross-tabulation data on irrigator behavior by the USDA Economic Research Service. ERS has subsequently developed and released an updated database.

Potential Changes in Future Regional Climate and Related Impacts

CLIMAS Investigator: J. Weiss

Research Collaborators: U.S. Department of Transportation - John A. Volpe National Transportation Systems Center; Mid-Region Council of Governments of New Mexico

Partners: U.S. Department of Transportation - Federal Highway Administration; U.S. Fish and Wildlife Service; National Park Service; and U.S. Bureau of Land Management

ABSTRACT

Similar to many other metropolitan areas in the western United States, Albuquerque and surrounding cities in central New Mexico comprise a rapidly growing region in an arid environment. Planning for such an area in the 21st century requires addressing a mixture of challenges from congestion, sprawl, energy use, vehicle emissions, water supply, and potential changes in future regional climate along with related impacts.

Led by the U.S. Department of Transportation's John A. Volpe National Transportation Systems Center, a group of federal agencies and the Mid-Region Council of Governments of New Mexico (MRCOG) is embarking on a project—the Central New Mexico Climate Change Scenario Planning Project—to help the region address these intertwined challenges. Through the process of scenario planning, which evaluates the costs and benefits of different types of growth, development, and investments, this project aims to influence regional transportation and land-use decision making and analyze strategies to reduce carbon emissions and prepare for impacts related to potential changes in future climate.

DELIVERABLES

(1) Publication:

Weiss, J. 2014. *Potential Changes in Future Regional Climate and Related Impacts - A Brief Report for the Central New Mexico Climate Change Scenario Planning Project.*

This report summarizes current research on selected potential changes in future regional climate and related impacts. Information regarding future climate change is based largely on recent synthesis reports at regional, national, and international levels.

Other Funding Sources:

U.S. Department of Transportation - Federal Highway Administration; Fish and Wildlife Service; U.S. National Park Service; U.S. Bureau of Land Management

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

CLIMAS Investigators: M. Wilder, G. Garfin, G. Frisvold, J. Brugger, and A. Quijada-Mascareñas

Research Collaborators: C. Presnall (Univ. of Arizona - Udall Center for Studies in Public Policy); P. Romero Lankao (National Center for Atmospheric Research); M. Ibarra, M. Montero (Comisión Nacional del Agua (CONAGUA) and Servicio Meteorológico Nacional); L. Farfan (Centro de Investigación Científica y de Educación Superior de Ensenada (CICESE)); L. Brito (Centro de Investigaciones Biológicas del Noroeste (CIBNOR)); 7) C. Neri (Univ. Nacional Autónoma de México); and N. Pineda (El Colegio de Sonora)

Partners: World Wildlife Fund; ProNatura; Sonoran Institute; Tucson Water; Agua de Hermosillo; U.S. Geological Survey; and Instituto Nacional de Investigaciones Forestales Agrícolas y Pecuarias (INIFAP)

ABSTRACT

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

Other Funding Sources:

NOAA Sectoral Applications Research Program; Regional Climate Services Directors; Univ. of Arizona – Udall Center for Studies in Public Policy

Climate Science

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

CLIMAS Investigators: G. Garfin, H. Chang, and M. Switanek

Research Collaborators: The Nature Conservancy in New Mexico

Partners: New Mexico Interstate Stream Commission; U.S. Bureau of Reclamation; and Upper Gila Watershed Alliance

ABSTRACT

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

DELIVERABLES

(1) Publication:

Garfin, G., H. Chang, and M. Switanek. 2014. Chapter 3. Climate and Hydrology of the Upper Gila River Basin. In *Gila River-Arizona Water Settlement Act Ecological Flows Report*, D. Gori and M. Schumann (eds.). Santa Fe, NM: The Nature Conservancy. In this chapter, we examined historic and projected records of climate factors for the Southwest, with a focus on the Upper Gila River Basin in New Mexico. This report will inform decisions by the state regarding future diversions of the Upper Gila River

(2) Presentations:

Climate and Hydrology. Gila River Ecological Flows Project Team Meeting. November 2013, Albuquerque, NM.

Climate Change and Gila River Flows. Gila River Ecological Flows Workshop. January 2014, Albuquerque, NM.

Other Funding Sources:

The Nature Conservancy via Reclamation Water Smart



LYDIA BELL

Seasonality Matters: Changing Temperature Distributions across the Southwest

CLIMAS Investigators: Z. Guido and J. Swetish

ABSTRACT

Recent gridded global temperature analyses have shown that temperature distributions are, on average, shifting in mean and variance. They have also shown that the frequency of extreme temperatures is occurring at much greater percentages than in the past and at frequencies greater than their statistical properties would suggest. This project follows a similar methodology as Hansen et al. (2012)—one of the recent global temperature analyses—to assess how seasonal minimum, maximum, and average temperature distributions have changed in the instrumental record across Arizona, New Mexico, Utah, and Colorado. Researchers focus on quantifying changes in distributions and extreme temperatures in 20-year periods between 1931 and 2010 for each Historical Climate Network station in the four states and compare these results to global analyses. This local, station-based analysis provides insights about seasonal changing temperatures at scales more appropriate to local decision makers.

DELIVERABLES

(1) Presentations:
Results have been used in multiple presentations to local decision makers. Some results include:

Temperature distributions across the Southwest have shifted in recent decades compared to earlier decades.

The percentage of stations experiencing seasonal extreme temperature conditions (i.e., 90th and 95th percentile temperature) has increased in recent decades.



Stakeholder-Relevant CMIP5 Climate Projections for the Southwest: A Collaboration with NOAA-ESRL

CLIMAS Investigators: Z. Guido, D. Ferguson, J. Overpeck, and J. Weiss
Research Collaborators: NOAA – Earth Systems Research Laboratory, Climate Analysis Branch

ABSTRACT

CLIMAS is identifying stakeholder-relevant climate projections for the Southwest, including extreme events, from stakeholders across the breadth of CLIMAS projects. Using this information, CLIMAS and the NOAA Earth System Research Laboratory, Climate Analysis Branch, will evaluate the ability of the latest generation of climate models—those from the Intergovernmental Panel on Climate Change (IPCC) AR5/CMIP5 models as well as regional models derived from these—to simulate and project the identified analyses. NOAA ESRL processes the resources needed to store and analyze the full suite of CMIP5 model simulations from the 20 international modeling groups. When projections meet performance measures deemed adequate for the decision, CLIMAS will generate the projections. Moreover, CLIMAS will produce a reference guide to help decision makers and CLIMAS PIs understand the limitations and advantages of different models and climate variables. This project will also help ESRL refine its online climate projection tool.

Other Funding Sources: NOAA Earth Systems Research Laboratory

Communicating Science

Planning for Local Government Climate Challenges: Connecting Research and Practice

CLIMAS Investigators: D. Ferguson, Z. Guido, J. Galayda, R. Thomas, G. Owen, and A. Meadow

Research Collaborators: J. Buizer (Univ. of Arizona - Institute of the Environment); N. Chetri, A. Reichman (Arizona State Univ. - Global Institute for Sustainability); R. Quay (Arizona State Univ. - Decision Center for a Desert City); and M. Roy (Arizona State Univ. - Office of the President)

Partners: Flagstaff City Manager's Office; Flagstaff Public Works; Flagstaff Policy Department; City of Phoenix Environment Program; and Pima Association of Governments Environmental Program

ABSTRACT

As the southwestern United States moves into an increasingly different climate than anything experienced in the modern era, elected officials, city managers, urban sustainability officers, planners, and resource managers are facing decisions that are likely to benefit from insights that emerge from ongoing climate science, impacts research, and promising adaptation practices. In an effort to both inform these decisions and learn from these important stakeholders in Arizona, this project seeks to create a collaborative environment among stakeholders and climate researchers to stimulate and support climate adaptation and resiliency efforts across the state. The project has three goals: provide useful, state-of-the-art climate knowledge to municipal leaders to encourage using climate science in long-range decision processes; work with urban managers and planners to develop tangible products and/or processes that will help planners and decision makers incorporate climate information into their unique planning documents and policies; study the process of engagement and results from the collaboration to contribute to the growing literature about best practices for climate change adaptation.



DELIVERABLES

(1) Publication:

Ferguson, D., R. Thomas, Z. Guido, L. Ethen, C. Zucker, G. Chorover, and R. Johnson. 2014. *Planning for Change in Southern Arizona: A report from the Southern Arizona Regional Climate Summit for Municipal Leaders*. Tucson: Climate Assessment for the Southwest. www.climas.arizona.edu/sites/default/files/pdfplanning-change-2014.pdf. This report synthesizes data we collected from participants in the November 2013 Climate Summit and suggests potential next steps for developing regional coordination of climate adaptation planning in southern Arizona

(2) Workshops:

Regional Climate Summit for Municipal Leaders: Economic, Health, Water & Transportation Impacts. November 2013. Tucson, AZ. This workshop was planned with a small committee of stakeholders to bring together southern Arizona municipal leaders (e.g., local politicians, upper level municipal management) to explore the risks, potential costs, and proactive solutions necessary to combat and cope with climate change challenges affecting southern Arizona. The planning committee wanted this workshop to help spur action and regional coordination of climate adaptation planning.

Flagstaff Climate Adaptation and Resiliency Planning Workshop. October 2013, Flagstaff, AZ. To advance climate resiliency planning, the City of Flagstaff partnered with members of CLIMAS, Arizona State University's Decision Center for a Desert City, and Center for Integrated Solutions to Climate Challenges (The Climate Center) to develop climate resiliency performance measures.

Other Funding Sources:

NOAA Sectoral Applications Research Program

Transborder Climate Communication

CLIMAS Investigators: G. Garfin, M. Wilder, and A. Quijada-Mascareñas

Research Collaborators: D. Brown, M. Muth (NOAA); M. Ibarra, M. Montero, D. Cruz-Torres, M. Andrade, J. Vazquez (Comisión Nacional del Agua (CONAGUA); Servicio Meteorológico Nacional); L. Farfan (Centro de Investigación Científica y de Educación Superior de Ensenada (CICESE)); L. Brito (Centro de Investigaciones Biológicas del Noroeste (CIBNOR)); C. Cote, A. Howard (Environment Canada); and M. Shafer, A. Krautmann (Southern Climate Impacts Planning Program)

Partners: World Wildlife Fund; ProNatura; U.S. Geological Survey; and Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias

ABSTRACT

Climate and its impacts extend across the U.S.-Mexico border, affecting many economic activities, including the management of natural resources, agriculture and ranching, and public health. This project aims to provide information on climate and the environment for the binational border region and assess the effectiveness of social media for building the capacity to convey and use climate information in decision making.

DELIVERABLES

(1) Decision Support:

Rio Grande/Bravo Climate Impacts & Outlook, Winter 2013-14. This is the first of multiple experimental quarterly binational/bilingual climate outlooks designed to provide climate information to stakeholders in the Rio Grande/Rio Bravo transboundary river basin.

The product is produced on behalf of the North American Climate Services Partnership, a collaboration between the weather services of Canada, the United States, and Mexico. This is also part of a National Integrated Drought Information System (NIDIS) pilot project for the Rio Grande/Rio Bravo transboundary region.

<http://drought.gov/media/pgfiles/Rio-Grande-Bravo-Climate-Outlook13.pdf>

<http://drought.gov/media/pgfiles/Rio-Grande-Bravo-Climate-Outlook-spanish3.pdf>

(2) Presentation:

Garfin, G., M. Shafer, and D. Brown. 2013. Cooperation on Climate Services in the Binational Rio Grande/Bravo Basin. American Geophysical Union. December 2013, San Francisco, CA.

Other Funding Sources:

NOAA Sectoral Applications Research Program; NOAA National Climatic Data Center; NOAA Regional Climate Services Directors

Climate in Context (RISA Book)

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

Research Collaborators: A. Parris (NOAA – Climate Program Office); K. Dow (Univ. of South Carolina); R. Nelson (Univ. of Tasmania); and R. Meyer (California Ocean Science Trust)

ABSTRACT

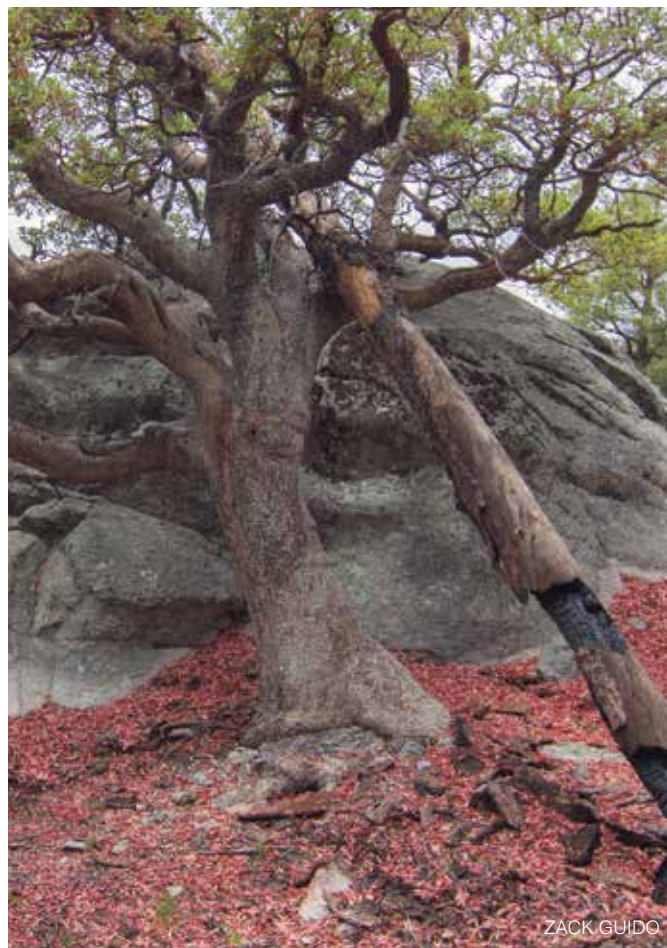
Climate in Context is an edited volume describing the development and implementation of the NOAA RISA program, an innovative program to research and develop experimental region-based climate services. The book covers scholarly contributions on use-inspired research in five key areas, including understanding the context of working with stakeholders and decision makers, understanding risk-based climate applications, supporting the development of knowledge networks, innovating regional climate services, and advancing science policy. The book editors are Adam Parris, Gregg Garfin, and an editorial working group of applied climate and science policy experts. The book will be published by Wiley & Sons; the expected date of publication is fall 2014.

DELIVERABLES

(1) Presentation:

Climate in Context. RISA Meeting. December 2013, La Jolla, CA.

Other Funding Sources: NOAA Climate Program Office



ZACK GUIDO

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

CLIMAS Investigators: G. Garfin and J. Brugger

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

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

ABSTRACT

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

Other Funding Sources: NOAA Climate Program Office

The Southwest Climate Outlook

CLIMAS Investigators: Z. Guido, G. Garfin, M. Crimmins, D. DuBois, and J. Dollin

Research Collaborators: Arizona Cooperative Extension; Office of the State Climatologist for Arizona; Univ. of Arizona - Institute of the Environment; Office of the State Climatologist for New Mexico; and New Mexico State Univ.

ABSTRACT

The Southwest Climate Outlook (SWCO) summarizes climate and weather information from disparate sources in nonscientific language, providing about 1,500 readers with timely climate-related information. Since SWCO's inception in 2002, stemming from the END InSight project, the publication has evolved into a tool for two-way communication with stakeholders and a platform for responding to needs throughout the region. The diverse SWCO audience includes water managers, farmers, ranchers, research scientists, interested citizens, and others.

DELIVERABLES

(1) Decision Support:

The *Southwest Climate Outlook* Newsletter (SWCO) synthesizes and interprets climate and climate impacts information specific to the U.S. Southwest. This has been an ongoing project that was initially implemented in 2002 in response to stakeholder demand and was tailored with stakeholder feedback. Since then, SWCO has been operational without direct input from users. Monthly issues are found here: <http://www.climas.arizona.edu/swco>



SOLMAZ OSMAN

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

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

Research Collaborators: DHS – Federal Emergency Management Agency; NOAA – National Weather Service Western Region; and DOI – Southwest Climate Science Center

Partners: Region 9 of the Federal Emergency Management Agency and NOAA – National Weather Service Western Region

ABSTRACT

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

DELIVERABLES

(1) Decision Support:

A suite of custom climate maps (e.g., historical precipitation patterns, flood impacts) to meet a FEMA-specified need. These maps will be operationally integrated into a "dashboard" to provide monthly guidance on historical flood risk.

A custom climate information system for FEMA led to the development of the above-mentioned dashboard of flood risk information, including the creation of flood impact and precipitation climatologies.

Other Funding Sources:

NWS – Western Regional Headquarters; Federal Emergency Management Administration



TreeFlow Transition

CLIMAS Investigators: C. Woodhouse and B. Brice

Research Collaborators: Univ. of Arizona – Institute of the Environment

ABSTRACT

TreeFlow (treeflow.info) is a comprehensive Web resource on tree-ring reconstructions of streamflow and climate for the western U.S., providing access to data for 70 streamflow reconstructions as well as information on data development and applications. While the primary users of streamflow reconstructions are water resource professionals, people in many other sectors and disciplines may find the data useful. TreeFlow is a collaborative effort between two RISA programs, CLIMAS and the Western Water Assessment (WWA) at the University of Colorado. The TreeFlow website has been housed on a server at the University of Arizona but the web master, Jeff Lukas of WWA, expressed the desire to step down from this responsibility in the summer of 2013. In order to make updating easier, we decided to move the current Treeflow set of Web pages to a Drupal platform. The goal of this CLIMAS project has been to make that transition. Multiple end-users utilize the information on TreeFlow. This resource, and the workshops that are a part of it, have broadened the perspectives of water resource managers beyond the scope of the instrumental record and have provided an additional tool for resource management. Lists of workshop attendees who have been interested in using tree rings in water resource management can be found here <http://treeflow.info/workshops.html>.

Other Funding Sources:

NOAA – National Climatic Data Center Paleoclimatology Program; National Integrated Drought Information System (NIDIS)

Drought

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

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

Partners: Hopi Department of Natural Resources and Navajo Nation Department of Water Resources

ABSTRACT

The Hopi Tribe and Navajo Nation have been experiencing widespread and persistent drought conditions for more than a decade. Drought has impacted vegetation and local water resources in ways that threaten agricultural systems and ecosystems that are critical to supporting the Hopi and Navajo people. Limited hydroclimatological and ecological monitoring across the region has made it difficult to assess current drought impacts and anticipate future impacts. By working with Navajo and Hopi resource managers to develop better drought monitoring tools and tactics, this research aims to help these two communities reduce their vulnerability to drought, cope with unavoidable drought impacts, and plan for long-term sustainability in the region.



DELIVERABLES

(1) Decision Support:

Hopi Department of Natural Resources Quarterly Drought Status Summary (pilot): Initial product developed in March 2014 in cooperation with Hopi DNR. This Drought Status Summary lists impact information collected by Hopi DNR staff and summarizes regional drought information.

(2) Presentations:

Three Drought Impacts Monitoring Projects in 15 Minutes. California Department of Natural Resources and National Integrated Drought Information System Drought Impacts Reporting Workshop. July 2013, La Jolla, CA.

Developing a Regional Climatology for the Four Corners Region to Support Tribal Resource Management and Drought Planning. 12th Biennial Conference of Science and Management on the Colorado Plateau. September 2013, Flagstaff, AZ.

How Can Local Observations of Drought Impacts Help Support Long-term Climate Adaptation Planning? 12th Biennial Conference of Science and Management on the Colorado Plateau. September 2013, Flagstaff, AZ.

Resources for Climate Adaptation Planning in the Southwest. Inter-Tribal Council of Arizona's Tribal Environmental Managers Working Group Meeting. September 2013, San Carlos, AZ.

Assessing and Supporting Drought Monitoring Needs on the Hopi and Navajo Nations. NOAA SARP Webinar Series: Climate Information for Managing Risks in Water Resources. December 2013, Virtual.

Trees as Drought Impact Recorders in the Tribal Lands of the Four Corners, USA. Annual Meeting of the Association of American Geographers. April 2014, Tampa, FL.

Three-Season Hydroclimatic Variability from Tree Rings in the Four Corners Region, USA. Annual Meeting of the Association of American Geographers. April 2014, Tampa, FL.

Other Funding Sources:

NOAA – Sectoral Applications Research Program; National Integrated Drought Information System (NIDIS); NASA Space Grant

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. Masayesva

Partners: Hopi Department of Natural Resources and Hopi Tribal Government

ABSTRACT

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

DELIVERABLES

(1) Decision Support: Experimental Quarterly Hopi Drought Summary report (first issue was released in early April 2014). This product synthesizes various data sources that reflect ongoing drought status on Hopi lands. The drought summary is designed to provide the HDNR with a status update on drought conditions and demonstrate to HDNR technicians how the data they collect may be used.

Other Funding Sources:

NOAA – Sectoral Applications Research Program; National Integrated Drought Information System (NIDIS)



Economics & Livelihoods

Climate Mitigation and Agriculture: Public Policy Education

CLIMAS Investigators: G. Frisvold, X. Vu, and H. Richards

Research Collaborators: B. Hurd (New Mexico State Univ. - Agricultural Economics and Agricultural Business); D. Fort (Univ. of New Mexico Law)

Partners: Cotton Incorporated; National Cotton Council; and American Farmland Trust

ABSTRACT

This project involves economic evaluations of the effects of actual and proposed climate change mitigation policies. It compares and contrasts state energy and carbon emission intensity and climate mitigation policies, seeking to examine how state resource endowments affect policy development and resource use. It also examines strategies to sequester carbon or reduce carbon emissions.



ZACK GUIDO

DELIVERABLES

(1) Publications:

Frisvold, G. and K. Konyar. 2013. Climate change mitigation policies: Implications for agriculture and water resources. *Journal of Contemporary Water Research & Education* 151(1):27-42. Climate change mitigation policies such as cap and trade with carbon offsets may encourage significant water conservation in some U.S. regions but increase competition for water in others. By reducing fertilizer use and dramatically altering land-use patterns across the Mississippi basin, these policies may provide unexpected water quality benefits.

Richards, H. 2013. *The Footprint of Growth: A Multi-faceted Environmental Kuznets Curve Analysis of CO₂ Emissions in the U.S.* M.S. Thesis. Department of Agricultural and Resource Economics. University of Arizona. State-level natural resource endowments and per capita income are important determinants in trade-embodied carbon emissions, carbon intensity of energy production, and energy intensity of production. Consumption-based emissions, which account for emissions embodied in net electricity imports, can diverge significantly from production-based emissions.

Frisvold, G. 2014. Effects of Climate Change Legislation on US Cotton Producers. In *2014 Proceedings of the Beltwide Cotton Conferences*. January 2014, New Orleans, LA. Memphis, TN: National Cotton Council. A multi-region mathematical programming model of U.S. agriculture estimated that the proposed American Clean Energy and Security Act (H.R. 2454) would reduce U.S. cotton production by 17 percent if cap-and-trade provisions were combined with land retirement for carbon sequestration. Reducing fertilizer use and cropland acreage in the Mississippi basin may reduce hypoxia problems in the Gulf of Mexico.

(2) Decision Support:

USARM model was updated for projections to 2020 and to 2030. The model provides for more accurate policy scenarios accounting for future conditions.

(3) Presentation:

Frisvold, G. Climate Policy as Water Policy: Water Quality and Conservation Co-Benefits. Paper presented at Nexus 2014: Water, Food, Climate and Energy Conference. March 2014, Chapel Hill, NC. The analysis addresses a stakeholder need by measuring co-benefits of climate change mitigation policies. While climate change legislation entails certain costs, it also entails benefits in addition to mitigation benefits. These co-benefits are an additional argument for adopting these policies.

Other Funding Sources:

Economic Research Service; Cotton Incorporated; NSF – New Mexico Experimental Program to Stimulate Competitive Research (NMESPCoR)

Climate Change Mitigation Strategies and Policies

CLIMAS Investigators: G. Frisvold, G. Pfeffer, and T. Marquez

Research Collaborators: A. Barnhart (Univ. of Arizona - Institute of the Environment) and W. Ela (Univ. of Arizona - Department of Chemical and Environmental Engineering)

Partners: Tucson Water; Tucson Metropolitan Energy Commission; Navajo Nation; and U.S. Bureau of Reclamation

ABSTRACT

This project involves economic evaluations of the effects of actual and proposed climate change mitigation policies. It compares and contrasts state energy and carbon emission intensity and climate mitigation policies, seeking to examine how state resource endowments affect policy development and resource use. It also examines strategies to sequester carbon or reduce carbon emissions, particularly through the adoption of renewable energy technologies.

DELIVERABLES

(1) Publications:

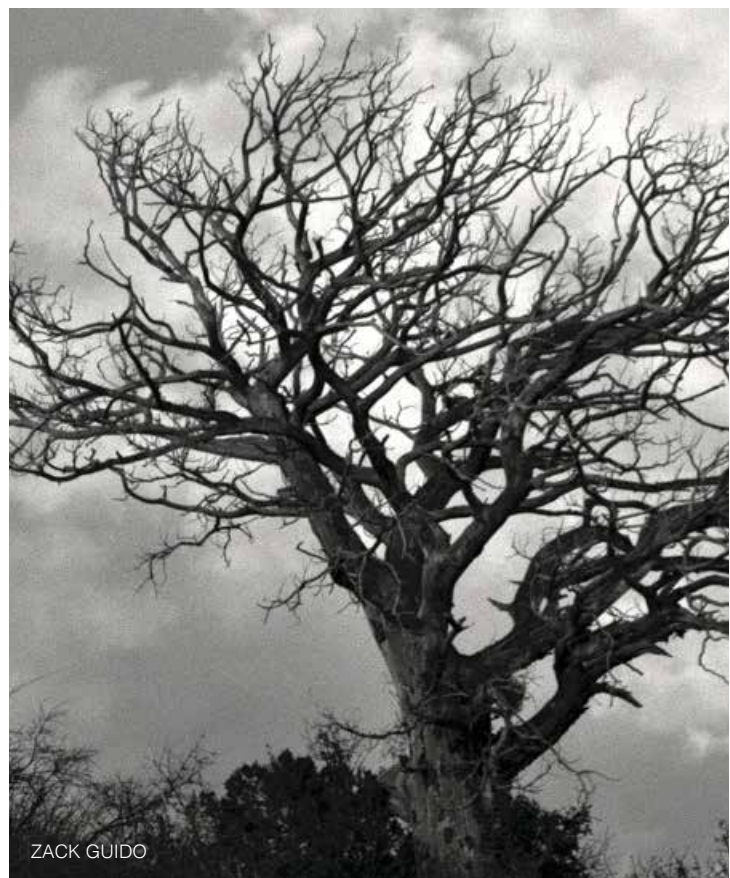
Frisvold, G. and T. Marquez. 2013. Water requirements for large-scale solar energy projects in the West. *Journal of Contemporary Water Research & Education* 151(1):106-116. Water requirements to meet five western states' Renewable Portfolio Standards for electricity generation using solar thermal technology would reach 0.8 percent of regional water consumptive use by 2035 assuming the most water-intensive technology and 0.2 percent based on average water intensities of current plants.

Pfeiffer, G. 2013. *Diffusion of Solar Technology in Agriculture*. M.S. Thesis. Department of Agricultural and Resource Economics. University of Arizona. State-level differences in on-farm adoption of solar technology could be explained largely by solar radiation, electricity price, and utility expenditures as a share of farm production costs. Grant programs and sales tax incentives also positively affect adoption.

Marquez, T. 2013. *Factors Influencing the Deployment of Utility Scale Solar Power in the United States*. M.S. Thesis. Department of Agricultural and Resource Economics. University of Arizona. Conducting survival analysis across U.S. states, the thesis found that first construction of a utility-scale solar facility in a state was accelerated by solar radiation potential, growth in population relative to electricity generating capacity, renewable portfolio standards with specific solar carve-outs, and tax subsidies for renewable energy development.

Other Funding Sources:

USDA - National Needs Fellowship Program; U.S. Bureau of Reclamation; Arizona TRIF



Sectoral Impacts of Drought and Climate Change

CLIMAS Investigators: G. Frisvold, J. Flaherty, and G. Jin

Research Collaborators: L. Norman (U.S. Geological Survey, Tucson, AZ); K. Konyar (California State Univ., San Bernardino - Department of Economics); S. Ponnaluru (Washington State Univ. - School of Economic Sciences Impact Center); A. Kerna (Univ. of Arizona - Department of Agricultural and Resource Economics); S. Hecht (Univ. of California, Los Angeles - School of Law); E. Büyüktaktakin (Wichita State Univ. - Department of Manufacturing and Industrial Engineering); F. Szidarovszky (Univ. of Arizona - Department of Systems and Industrial Engineering); and Z. Feng (Arizona State Univ. - Department of Computer Science and Engineering)

Partners: National Parks Conservation Association; U.S. Bureau of Reclamation; Central Arizona Project; Cotton Incorporated; Arizona Agri-Business Council; Yuma County Water Users' Association; Greater Yuma Economic Development Corporation; Arizona House of Representatives, Agriculture and Water Committee; Arizona Farm Bureau; Wellton-Mohawk Irrigation District; Sonoran Institute; Southern Arizona Buffelgrass Coordinating Committee; and Wells Fargo Bank

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. The effects of drought on income and employment will be estimated.

DELIVERABLES

(1) Publications:

Frisvold, G., L. Jackson, J. Pritchett, J. Ritten, and M. Svoboda. 2013. Agriculture and Ranching. In *Assessment of Climate Change in the Southwest United States: A Report Prepared for the National Climate Assessment*, G. Garfin et al (eds.). Washington, DC: Island Press, p. 218-239. Effects of climate change and associated variability on production of both crops and livestock could be long lasting, with short-term reductions in profitability (medium-low confidence).

Büyüktaktakin, I., Z. Feng, A. Olsson, G. Frisvold, and F. Szidarovszky. 2014. Invasive species control optimization as a dynamic spatial process: An application to buffelgrass (*Pennisetum ciliare*) in Arizona. *Invasive Plant Science and Management* 7(1):132-146. Rule-of-thumb strategies for invasive buffelgrass control that are recommended under the Buffelgrass Strategic Plan are shown to reduce invasive species damage significantly relative to no control and control based on static optimization.

Büyüktaktakin, I., Z. Feng, G. Frisvold, and F. Szidarovszky. 2013. Invasive species control based on a cooperative game. *Applied Mathematics* 4(10B):54-59. Results highlight the importance of the spatial configuration of players and the resources they wish to protect in invasive species control problems.

Norman, L., M. Villarreal, R. Niraula, T. Meixner, G. Frisvold, and W. Labiosa. 2013. Framing scenarios of binational water policy with a tool to visualize, quantify and value changes in ecosystem services. *Water* 5(3):852-874. An approach is outlined for modeling and visualizing impacts of management decisions on rare terrestrial and aquatic wildlife, vegetation, surface water, groundwater recharge, real estate values, and socio-environmental vulnerable communities in the binational Santa Cruz Watershed. This approach identifies and quantifies ecosystem services from effluent from an international wastewater treatment facility and models the potential reduction in effluent discharge to the U.S. that is under scrutiny by binational water policymakers and is of concern to stakeholders.

Frisvold, G. and G. Jin. 2013. Effects of Weather Extremes on Cotton Acreage Abandonment and Insurance Indemnities. *Proceedings of the Beltwide Cotton Conferences*. Memphis, TN: National Cotton Council. Weather extremes are significant predictors of cotton crop abandonment, causing large losses in economic resources devoted to planting crops that are not harvested. Irrigation significantly mitigates effects of drought, but disruptions in irrigation supply can then lead to significant damages.

(2) Decision Support:

For the buffelgrass project, we have developed a decision tool that, when fully operational, would allow decision makers to use Excel to manage data layers, use cell formulae to maintain spatial and dynamic relationships, and use the chart function to produce maps of costs, damages, weed population, and treatment recommendations. The ILOG CPLEX software package, a powerful tool for solving linear integer (binary) programs, interfaces with Excel programs so that model solutions can be readily converted to treatment priority and other maps. Given manager priorities, the Excel / ILOG CPLEX program would allow managers to print out maps that show which areas to treat for invasive buffelgrass. We have been working with the Southern Arizona Buffelgrass Coordinating Committee (SABCC) to run additional simulations as requested. We are also working to develop improved treatment rules of thumb that would allow managers to prioritize treatment areas without having to re-run complex simulations.

(3) Presentations:

Frisvold, G. Weather Extremes and the Costs of Cotton Acreage Abandonment. Cotton Economics & Marketing Conference of the 2014 Beltwide Cotton Conferences. January 2014, New Orleans, LA. Cotton producers and industry groups are interested in mechanisms to cope with weather extremes and how new insurance products may assist in this.

Frisvold, G. The Contribution of Agriculture to the Yuma Economy. Presentation to the Committee on Agriculture and Water, Arizona House of Representatives. February 2014, Yuma, AZ. While agricultural-urban or agricultural-environmental water transfers have been identified as a key means to adapt to drought and climate change, there is concern in rural communities about the economic impacts of such "water exports." This was an invited presentation by state, county, and city officials and business leaders and has resulted in requests for further information and analysis (Agri-Business Council of Arizona, Arizona Farm Bureau, Office of Governor Jan Brewer, AZ).

Frisvold, G. Three presentations on the Drought, Crop Insurance, and the Farm Bill sponsored by Wells Fargo Bank. January 2014, Willcox, Casa Grande, and Yuma, AZ. Presentations were invited as part of an annual series of presentations that Wells Fargo Bank organizes for agricultural producers. There was special interest among producers on the effects of drought and on the structure of the new Farm Bill, which shifts most farm-income support programs to different types of insurance programs. This represents a significant policy change, and producers were interested in hearing how the new insurance programs might affect them.

Other Funding Sources:

U.S. Geological Survey; Bureau of Reclamation; U.S. National Park Service; Cotton Incorporated; Yuma County Arizona Cooperative Extension

Evaluation and Education

CLIMAS Project and Program Evaluation 2012-2017

CLIMAS Investigators: G. Owen and D. Ferguson

Partners: Other RISA programs and RISA Program Management

ABSTRACT

CLIMAS, like all the members of the larger network of Regional Integrated Sciences and Assessments (RISA) program, has a primary goal of providing relevant climate-related research to support decision making in our region. A fundamental, though frequently overlooked, element of this type of socially-engaged research is evaluation of the program and its constituent projects to understand whether we effectively connect climate science with decision makers; learn about what integrative activities work and why; demonstrate successes to funding agencies, stakeholders, and the public; and improve the overall program. This project and program evaluation effort is being led by Dan Ferguson and Gigi Owen, but it involves all CLIMAS researchers to first develop and articulate an overarching program theory of CLIMAS (i.e., why do we do the work we do), then develop and monitor metrics demonstrate how the program and its projects are functioning.



Making the Connection between Science and Decision Making - A Graduate Seminar

CLIMAS Investigators: C. Woodhouse and D. Ferguson

ABSTRACT

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

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

Health

Climate and Health

CLIMAS Investigators: A. Comrie, M. Butterworth, C. Morin, S. Sen, and H. Brown

Research Collaborators: K. Ernst, Y. Carriere, M. Riehle, and K. Walker (Univ. of Arizona - College of Public Health)

Partners: Santa Cruz County Health Department; Pima County Health Department; and Arizona Department of Health Services

ABSTRACT

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

DELIVERABLES

(1) Publications:

Morin, C. and A. Comrie. 2013. Regional and seasonal response of a West Nile virus vector to climate change. *Proceedings of the National Academy of Sciences (PNAS)* 110(39):15620-15625.

www.pnas.org/cgi/doi/10.1073/pnas.1307135110

Morin, C., A. Comrie, and K. Ernst. 2013. Climate and dengue transmission: Evidence and implications. *Environmental Health Perspectives* 121:1264-1272. <http://dx.doi.org/10.1289/ehp.1306556>

(2) Media Coverage:

How climate change may affect West Nile virus spread. 2013.

The Huffington Post. September 10. http://www.huffingtonpost.com/2013/09/10/climate-change-west-nile-spread-mosquitoes_n_3896027.html

Peebles, L. 2013. Dengue fever: Another formidable World Cup opponent. *The Huffington Post*. December 6. www.huffingtonpost.com/2013/12/06/dengue-world-cup-brazil_n_4392426.html



Air Quality and Climate

CLIMAS Investigators: D. DuBois, R. Armenta, and Y. Zhou

Research Collaborators: C. Rincon (Environmental Protection Agency - Region 6); M. Flores, S. Engle, M. Bleiweiss, M. Bean, R. Duran (New Mexico State Univ. - Plant and Environmental Sciences); R. Fitzgerald, T. Gill (Univ. of Texas El Paso); V. Etyemezian, G. Nikolich (Desert Research Institute); I. Kavouras (Univ. of Arkansas Medical Sciences); J. Flores Marguez (Univ. Autonoma de Ciudad Juarez); M. Baca (New Mexico Environment Department–Air Quality Bureau); V. Valenzuela (Texas Commission on Environmental Quality); G. Tarin Torres (SEMARNAT-Chihuahua); A. Siwki (U.S. Co-Leader of the New Mexico-Chihuahua Rural Task Force); and P. Edmunds (Border Partners)

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

ABSTRACT

Dust storms in the Southwest U.S. and northern Mexico continue to be a serious health and safety issue. With an increasing number of valley fever diagnoses each year, this has elevated its priority as a critical disease across the region. Spores that live in southwestern soils cause valley fever; these spores easily travel via dust storms. As part of this project, a pilot-scale health study with data from one hospital has been conducted in southern New Mexico to gauge impacts of air quality on health. During the study we also found a great need in forecasting wind events, especially those that coincide with drought. We use both ground-based air quality monitoring and satellite remote sensing of dust plumes to determine areas impacted and areas where dust has originated. Another goal is to improve short-term dust forecasts and those coupled with seasonal forecast model output to provide longer lead times for dust events.



MARY ELLEN CLARK

DELIVERABLES

(1) Publications:

Rodopoulou, S., M. Chalbot, E. Samoli, D. DuBois, B. San Filippo, and I. Kavouras. 2014. Air pollution and hospital emergency room and admissions for cardiovascular and respiratory diseases in Doña Ana County, New Mexico. *Environmental Research* 129:39-46. doi: 10.1016/j.envres.2013.12.006 Significant correlations were found between ozone, PM10, PM2.5 and emergency room and hospital admissions in Las Cruces, NM.

Hernandez Escamilla, J., J. Flores Margez, M. Ramirez, N. Mendoza, M. Rios, M. Shukla, and D. DuBois. 2013. Artículo de investigación, material particulado dispersado al aire en áreas sin asfalto en Ciudad Juárez. *Ciencia en la frontera: revista de ciencia y tecnología de la UACJ*, Vol. XI, Ciudad Juárez, Chih.: UACJ, p. 9-14. Unpaved roads were characterized at several urban Ciudad Juárez city streets to measure road-side exposures.

Chalbot, M., I. Kavouras, and D. DuBois. 2013. Assessment of the contribution of wildfires on ozone concentrations in the central U.S.-Mexico border region. *Journal of Aerosol and Air Quality Research* 13:838-848. doi: 10.4209/aaqr.2012.08.0232 The importance of wildfires on regional ozone levels were determined in this study of U.S. border region ozone monitoring station data.

Smith, E. 2014. *Dust Abatement in the Mesilla Valley*. MS Thesis. Department of Plant and Environmental Sciences, New Mexico State University. In this study we successfully demonstrated several dust control techniques over disturbed suburban landscapes over the course of a year and half. <http://nmborderair.nmsu.edu/past-studies-and-inventories/dust-control-study/>

Five reports prepared for the Department of Health, Office of Border Health (Assessments of Land-based Sources of Air Quality Contaminants in the Binational Border Region of Southwestern New Mexico, Northwestern Chihuahua and West Texas).

Three reports prepared for the New Mexico Environment Department, Air Quality Bureau.

(2) Decision Support:

Developed protocol for pollen sampling, using locally found materials (Las Cruces, NM). Protocol can be used to easily collect pollen and fungi. A particle atlas identifies what can be found in a typical sample.

(3) Presentations:

Two presentations at Dust Summit for the City of Las Cruces. Communicated information about the hazards of dust and ways to mitigate it in suburban areas of Las Cruces. Las Cruces, NM, February 19, 2014.

(4) Workshops:

Jointly conducted between NMSU and the Border 2012 New Mexico-Chihuahua Rural Task Force. Topics included health effects of particulates, protection from high levels of dust, and potential exposure to valley fever. Columbus, NM & Palomas, Chihuahua, November 2013.

Other Funding Sources:

U.S. EPA Border 2012; New Mexico Department of Health

CLIMAS Publications 2013-2014

- Ault, T., J. Cole, J. Overpeck, G. Pederson, and D. Meko. 2013. Assessing the risk of persistent drought using climate model simulations and paleoclimate data. *Journal of Climate* (In press). <http://dx.doi.org/10.1175/JCLI-D-12-00282.1>
- Bilal, M., J. Nichol, M. Bleiweiss, and D. DuBois. 2013. A simplified high resolution MODIS Aerosol Retrieval Algorithm (SARA) for use over mixed surfaces. *Remote Sensing of Environment* 136:135-145. doi: 10.1016/j.rse.2013.04.014
- Bleiweiss, M. and D. DuBois. 2013. Dust Source Locations from Remote Sensing Report for the Windblown Dust Emission Inventory for the International Border Region of Southern New Mexico. Report for the NM Environment Department, Air Quality Bureau.
- Brusca R., J. Wiens, W. Meyer, J. Eble, K. Franklin, J. Overpeck, and W. Moore. 2013. Dramatic response to climate change in the Southwest: Robert Whittaker's 1963 Arizona mountain plant transect revisited. *Ecology and Evolution* 3(10):3307-3319. doi: 10.1002/ece3.720
- Büyüktaktakın, İ., Z. Feng, A. Olsson, G. Frisvold, and F. Szidarovszky. 2014. Invasive species control optimization as a dynamic spatial process: An application to buffelgrass (*Pennisetum ciliare*) in Arizona. *Invasive Plant Science and Management* 7(1):132-146.
- Büyüktaktakın, İ., Z. Feng, G. Frisvold, and F. Szidarovszky. 2013. Invasive species control based on a cooperative game. *Applied Mathematics* 4(10B):54-59.
- Chalbot, M., I. Kavouras, and D. DuBois. 2013. Assessment of the contribution of wildfires on ozone concentrations in the central US-Mexico border region. *Journal of Aerosol and Air Quality Research* 13:838-848. doi: 10.4209/aaqr.2012.08.0232
- DuBois, D., I. Kavouras, and M. Chalbot. 2013. Correlation of Human Health Conditions with Air Quality in the Border Binational Region of Southwestern NM-NM Chihuahua-West Texas. Prepared for the Department of Health, Office of Border Health. <http://nmborderair.nmsu.edu/past-studies-and-inventories/health-assessment/>
- DuBois, D., I. Kavouras, M. Chalbot, M. Bean, M. Bleiweiss, R. Fitzgerald, and S. Engle. 2013. Modeling of Air Quality for the Assessment of Land-based Sources of Air Quality Contaminants in the Binational Border Region of Southwestern New Mexico, Northwestern Chihuahua and West Texas. Prepared for the Department of Health, Office of Border Health.
- DuBois, D., I. Kavouras, M. Chalbot, M. Lytle, E. Smith, R. Armenta, M. Bleiweiss, Y. Zhao, and S. Engle. 2013. Determination of Actual and/or Most Probable Causes and Sources of Air Quality Contamination in the Border Region of Southwestern New Mexico-Northwestern Chihuahua-West Texas. Prepared for the Department of Health, Office of Border Health.
- DuBois, D., I. Kavouras, M. Chalbot, M. Lytle, E. Smith, R. Armenta, M. Bleiweiss, Y. Zhao, and S. Engle. 2013. Descriptive Recommendations for Reducing Air Quality Contamination Specific to Causes, Sources, and Locations using BACT and BMPs. Prepared for the Department of Health, Office of Border Health.
- DuBois, D., S. Sanogo, M. Bleiweiss, and M. Bean. 2013. Pollen Measures and Dispersion Studies. Prepared for the Department of Health, Office of Border Health. <http://nmborderair.nmsu.edu/past-studies-and-inventories/pollen-measures-and-dispersion-studies/>
- DuBois, D. and Y. Zhao. 2013. Measurements of Wind Erosion using the PI-SWERL for the Windblown Dust Emission Inventory for the International Border Region of Southern New Mexico. Report for the NM Environment Department, Air Quality Bureau.

- Frisvold, G. 2014. Effects of Climate Change Legislation on US Cotton Producers. In *2014 Proceedings of the Beltwide Cotton Conferences*. January 6-8, 2014, New Orleans, LA. Memphis, TN: National Cotton Council.
- Frisvold, G., and K. Konyar. 2013. Climate change mitigation policies: Implications for agriculture and water resources. *Journal of Contemporary Water Research & Education* 151(1):27-42.
- Frisvold, G., L. Jackson, J. Pritchett, J. Ritten, and M. Svoboda. 2013. Agriculture and Ranching. In *Assessment of Climate Change in the Southwest United States: A Report Prepared for the National Climate Assessment*, G. Garfin et al (eds.). Washington, DC: Island Press, p. 218-239.
- Frisvold, G. and G. Jin. 2013. Effects of weather extremes on cotton acreage abandonment and insurance indemnities. *Proceedings of the Beltwide Cotton Conferences*. Memphis, TN: National Cotton Council.
- Frisvold, G. and T. Marquez. 2013. Water requirements for large-scale solar energy projects in the west. *Journal of Contemporary Water Research & Education* 151(1):106-116.
- Ferguson, D., R. Thomas, Z. Guido, L. Ethen, C. Zucker, G. Chorover, and R. Johnson. 2014. *Planning for Change in Southern Arizona: A report from the Southern Arizona Regional Climate Summit for Municipal Leaders*. Tucson: Climate Assessment for the Southwest. www.climas.arizona.edu/sites/default/files/pdfplanning-change-2014.pdf
- Flores-Márquez, J., J. Hernández-Escamilla, M. Delgado-Ríos, A. Granados Olivas, and D. DuBois. 2014. Land-based Sources of Air Quality Contaminants in the Binational Border Region of Southwestern New Mexico, Northwestern Chihuahua, and West Texas. Submitted to the Border Environment Cooperation Commission.
- Garfin, G. 2013. Assessment of Climate change in the Southwest United States: Key Findings. *5th Annual Science on the Sonoita Plain Symposium*. June 8, 2013. Elgin, AZ: Cienegas Watershed Partnership, p. 5-7.
- Garfin, G., H. Chang, and M. Switanek. 2014. Chapter 3. Climate and Hydrology of the Upper Gila River Basin. In *Gila River-Arizona Water Settlement Act Ecological Flows Report*, D. Gori and M. Schumann (eds.). Santa Fe, NM: The Nature Conservancy in New Mexico.
- Garfin, G., G. Franco, H. Blanco, A. Comrie, P. Gonzalez, T. Piechota, R. Smyth, and R. Waskom. 2014. Ch. 20: Southwest. Climate Change Impacts in the United States. *The Third National Climate Assessment*, J. Melillo, T. Richmond, and G. Yohe (eds.). U.S. Global Change Research Program, p. 462-486. doi:10.7930/J08G8HMN.
- Garfin, G., G. Hakanson, S. LeRoy, and C. Greene. 2013. Fact Sheets for Chapters 3-20. In *Assessment of Climate Change in the Southwest United States: A Report Prepared for the National Climate Assessment*, G. Garfin, A. Jardine, R. Merideth, M. Black, and S. LeRoy (eds.). Washington, DC: Island Press. <http://www.swcarr.arizona.edu/key-findings>
- Garfin, G. and A. Jardine. 2013. Overview. In *Assessment of Climate Change in the Southwest United States: A Report Prepared for the National Climate Assessment*, G. Garfin, A. Jardine, R. Merideth, M. Black, and S. LeRoy (eds.). Washington, DC: Island Press, p. 21-36. <http://swcarr.arizona.edu/chapter/2>
- Hernandez Escamilla, J., J. Flores Margez, M. Ramirez, N. Mendoza, M. Rios, M. Shukla, and D. DuBois. 2013. Artículo de investigación, material particulado dispersado al aire en areas sin asfalto en Ciudad Juárez. *Ciencia en la frontera: revista de ciencia y tecnologia de la UACJ*, Vol. XI, Ciudad Juárez, Chihuahua: UACJ, p. 9-14.
- Kavouras, I., M. Chalbot, and D. DuBois. 2013. Receptor-Based Dust Source Analysis for the Windblown Dust Emission Inventory for the International Border Region of Southern New Mexico. Report for the NM Environment Department, Air Quality Bureau.

- Marquez, T. 2013. *Factors Influencing the Deployment of Utility Scale Solar Power in the United States*. M.S. Thesis. Department of Agricultural and Resource Economics, University of Arizona.
- Norman, L., M. Villarreal, R. Niraula, T. Meixner, G. Frisvold, and W. Labiosa. 2013. Framing scenarios of binational water policy with a tool to visualize, quantify and value changes in ecosystem services. *Water* 5(3):852-874.
- Overpeck, J. 2014. The Challenge of Biodiversity Adaptation Under Climate Change. In *Applied Studies in Climate Adaptation*, J. Palutikof, S. Boulter, J. Barnett, and D. Rissik (eds.). Wiley: Oxford (In press).
- Overpeck, J., G. Garfin, A. Jardine, D. Busch, D. Cayan, M. Dettinger, E. Fleishman, A. Gershunov, G. MacDonald, K. Redmond, W. Travis and B. Udall. 2013. Summary for Decision Makers. In *Assessment of Climate Change in the Southwest United States: A Report Prepared for the National Climate Assessment*, G. Garfin, A. Jardine, R. Merideth, M. Black, and S. LeRoy (eds.). Washington, DC: Island Press, p. 1-20. <http://swcarr.arizona.edu/chapter/one>
- Pfeiffer, G. 2013. *Diffusion of Solar Technology in Agriculture*. M.S. Thesis. Department of Agricultural and Resource Economics, University of Arizona.
- Richards, H. 2013. *The Footprint of Growth: A Multi-faceted Environmental Kuznets Curve Analysis of CO2 Emissions in the U.S.* M.S. Thesis. Department of Agricultural and Resource Economics, University of Arizona.
- Rodopoulou, S., M. Chalbot, E. Samoli, D. DuBois, B. San Filippo, and I. Kavouras. 2014. Air pollution and hospital emergency room and admissions for cardiovascular and respiratory diseases in Doña Ana County, New Mexico. *Environmental Research* 129:39-46. doi: 10.1016/j.envres.2013.12.006
- Rogers, J., K. Averyt, S. Clemmer, M. Davis, F. Flores-Lopez, P. Frumhoff, D. Kenney, J. Macknick, N. Madden, J. Meldrum, J. Overpeck, S. Sattler, E. Spanger-Siegfried, and D. Yates. 2013. *Water-smart power: Strengthening the U.S. electricity system in a warming world*. Cambridge, MA: Union of Concerned Scientists.
- Smith, E. 2014. *Dust Abatement in the Mesilla Valley*. M.S. Thesis. Department of Plant and Environmental Sciences, New Mexico State University. <http://nmborderair.nmsu.edu/past-studies-and-inventories/dust-control-study/>
- Vano, J., B. Udall, D. Cayan, J. Overpeck, L. Brekke, T. Das, H. Hartmann, H. Hidalgo, M. Hoerling, G. McCabe, K. Morino, R. Webb, K. Werner, and D. Lettenmaier. 2013. Understanding uncertainties in future Colorado River streamflow. *Bulletin of the American Meteorology Society* 95:59–78. <http://dx.doi.org/10.1175/BAMS-D-12-00228.1>
- Weiss, J. 2014. *Potential Changes in Future Regional Climate and Related Impacts: A brief report for the Central New Mexico Climate Change Scenario Planning Project*.
- Werner, K., K. Averyt, and G. Owen. 2013. River forecast application for water management: Oil and water? *Weather, Climate, and Society* 5(3):244-253.
- Wilder, M., G. Garfin, P. Ganster, H. Eakin, P. Romero-Lankao, F. Lara-Valencia, A. Cortez-Lara, S. Mumme, C. Neri, and F. Muñoz-Arriola. 2013. Climate Change and U.S.-Mexico Border Communities. In *Assessment of Climate Change in the Southwest United States: A Report Prepared for the National Climate Assessment*, G. Garfin, A. Jardine, R. Merideth, M. Black, and S. LeRoy (eds.). Washington, DC: Island Press, p. 340-384. <http://swcarr.arizona.edu/chapter/16>



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