

Western Water Assessment



2013 - 2014 ANNUAL REPORT



Western Water Assessment



University of Colorado **Boulder**



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<p>Principal Investigator Lisa Dilling, University of Colorado-Boulder</p>	<p>Co-Investigators Kristen Averyt, University of Colorado-Boulder Nolan Doesken, Colorado State University Robert Gillies, Utah State University Douglas Kenney, University of Colorado-Boulder Jeffrey Lukas, University of Colorado-Boulder Jason Neff, University of Colorado-Boulder Thomas Painter, California Institute of Technology Balaji Rajagopalan, University of Colorado-Boulder William Travis, University of Colorado-Boulder Klaus Wolter, University of Colorado-Boulder</p>
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Performance period covered in this report: January 1, 2013–May 30, 2014.



Introduction

The mission of the Western Water Assessment (WWA) is to identify and characterize regional vulnerabilities to and impacts of climate variability and change, and to develop information, products and processes to assist decision makers throughout the Intermountain West. Using multidisciplinary teams of experts in climate, hydrology, ecology, law, and policy, WWA works with decision makers across the Intermountain West to produce policy-relevant information about climate variability and change. By building relationships and networks of decision makers, our team is able to develop practical research programs and useful information products. WWA is formally part of the Cooperative Institute for Research in Environmental Sciences (CIRES) at the University of Colorado in Boulder and is physically located in NOAA’s David Skaggs Research Center. Our researchers and partners come from universities and federal institutions in Colorado, Wyoming, and Utah.

New Areas of Focus

Within the existing mission described above, WWA shifts its specific research foci from year to year to stay current with stakeholder needs and emerging research frontiers. New areas of focus and new partnerships developed in 2013-2014 are described in Table 1.

Table 1. New partnerships and areas of focus developed in 2013-2014.

New Area of Focus	Relevant Projects (see pp. 10-19)
State level climate vulnerability assessment External Program Evaluation	<ul style="list-style-type: none"> Colorado Climate Change Vulnerability Study Evaluation of NIDIS Upper Colorado Drought Early Warning System
New Partnership	Relevant Projects (see pp. 10-19)
University of Utah Urban Planning	<ul style="list-style-type: none"> Adaptation Guidance for Salt Lake City Department of Public Utilities
Weber Basin Water Conservancy District Colorado Energy Office USDA Northern Plains Regional Climate Hub	<ul style="list-style-type: none"> Weber Basin Climate Sensitivity Analysis Colorado Climate Change Vulnerability Study Exploring Regional Climate Service Collaborations

WWA Staff and Research Team

WWA is comprised of a core staff of four (Table 2) who focus on program management, research development and synthesis, and coordination of stakeholder interactions. In addition to the core staff shown below, WWA shares administrative support (Nancy Filice) and outreach staff (Amy Nacu-Schmidt) with the Center for Science and Technology Policy Research (CSTPR) at CU-Boulder in order to increase efficiency and leverage resources.

Table 2. WWA Core Office Staff

Lisa Dilling	Director	ldilling@colorado.edu
Jeff Lukas	Senior Research Associate	lukas@colorado.edu
Eric Gordon	Managing Director	esgordon@colorado.edu
Tim Bardsley	Utah Liaison	www.bardsley@gmail.com



WWA also works with a team of individual researchers at the University of Colorado and other institutions throughout the region. A full list of team members is provided in Table 3.

Table 3. Western Water Assessment Research Team

Team Member	Title	Expertise
Andersson, Krister	Assistant Professor, Political Science, Univ. of Colorado	Environmental governance
Averyt, Kristen	Associate Director for Science, CIRES	Climatology, energy-water, assessment processes
Barsugli, Joseph	Research Scientist, CIRES, Univ. of Colorado	Climate dynamics
Berggren, John	Graduate Research Assistant, Univ. of Colorado	Climate adaptation, water policy
Clifford, Kate	Graduate Research Assistant, Univ. of Colorado	Conservation decisionmaking
Cozzetto, Karen	Postdoctoral Research Associate, CIRES, Univ. of Colorado	Hydroclimatology, surface water hydrology and ecology, climate adaptation
Deems, Jeff	Research Scientist, CIRES, Univ. of Colorado	Climate and snow modeling
Dilling, Lisa	Director, Western Water Assessment Assistant Professor, Environmental Studies, Univ. of Colorado	Climate information and decisionmaking
Gordon, Eric	Managing Director, Western Water Assessment	Climate adaptation
Huisenga, Mary	Professional Research Assistant, Univ. of Colorado	Limnology, decision modeling
Kasprzyk, Joseph	Assistant Professor, Civil Engineering, Univ. of Colorado	Multi-objective analysis for water management
Kenney, Douglas	Director, Western Water Policy Program, Getches-Wilkinson Center for Natural Resources, Energy, and the Environment, Univ. of Colorado School of Law	Western water policy and law
Klein, Roberta	Managing Director, Center for Science and Technology Policy Research, Univ. of Colorado	Environmental policy
Livneh, Ben	Visiting Fellow, Western Water Assessment and CIRES, Univ. of Colorado	Hydrologic modeling
Lukas, Jeffrey	Senior Research Associate, Western Water Assessment	Paleohydrology, forest ecology
McNie, Elizabeth	Research Associate, CIRES, Univ. of Colorado	Science policy, program evaluation
Meldrum, James	Research Associate, Institute for Behavioral Studies, Univ. of Colorado	Applied environmental economics
Molotch, Noah	Assistant Professor, Dept. of Geography, Univ. of Colorado	Snow hydrology
Nania, Julie	Research Assistant, Getches-Wilkinson Center for Energy, Natural Resources, and the Environment, Univ. of Colorado School of Law	Tribal law
Rangwala, Imtiaz	Research Associate, CIRES, Univ. of Colorado	Regional climate change, climate of high elevation areas
Rajagopalan, Balaji	Professor, Civil Engineering, Univ. of Colorado	Water resources engineering
Ray, Andrea	Scientist, Climate Analysis Branch, NOAA ESRL Physical Sciences Division	Climate-society interactions, water management
Schneider, Dominik	Graduate Research Assistant, Univ. of Colorado	Snow hydrology



Team Member	Title	Expertise
Travis, William	Associate Professor, Geography, Univ. of Colorado	Natural hazards, climate impacts and adaptation
Udall, Bradley	Senior Fellow, Getches-Wilkinson Center for Natural Resources, Energy, and the Environment, Univ. of Colorado School of Law	Colorado River, hydrology, policy
Wessman, Carol	Professor, CIRES, Univ. of Colorado	Landscape ecology, remote sensing
Wolter, Klaus	Research Scientist, CIRES, Univ. of Colorado	Climatology and meteorology

WWA 2013-2014 Program Highlights

Major Research Findings

- With colleagues from the Salt Lake City Department of Public Utilities, the NOAA Colorado Basin River Forecast Center, and University of Utah, **Tim Bardsley** led the co-production of a study that found Salt Lake City's water supply could drop 1.8 to 6.5 percent for every degree Fahrenheit of warming in the region.
- While the September 2013 extreme rain and flood event along Colorado's Front Range was widely believed to be unprecedented, especially for the fall season, analysis by **Jeff Lukas, Joe Barsugli**, and **Klaus Wolter**, with colleagues at NOAA Earth Systems Research Laboratory showed that a September 1938 event had an eerily similar synoptic pattern, and similar results in terms of precipitation totals and flooding impacts on the Front Range.
- Winter temperatures in the Rocky Mountains are projected to warm more in the future than lower-elevation regions at the same latitude, according to an analysis of CMIP5 global climate model runs by **Imtiaz Rangwala** and colleagues at Rutgers University.
- The worst watershed stresses seen across the country between 1999 and 2007 could become the new normal under a warming climate, according to research by **Kristen Averyt** and **James Meldrum**, along with colleagues from the USDA, Tufts University, and the Union of Concerned Scientists.
- Future projected changes in temperature and precipitation could exacerbate the effects of dust deposition on snowpack in the Upper Colorado River Basin, inducing additional losses of 10 to 20% of flow and earlier runoff timing shifts of 10-20 days relative to current climate and moderate dust conditions, according to research by **Jeff Deems** and **Joe Barsugli**.



Select Outreach Activities

Rapid Response to Colorado Front Range Flooding

In the wake of historic flooding across Colorado's Front Range, **Jeff Lukas** led the development of a four-page assessment report and a widely attended public briefing (Figure 1) discussing the meteorological, climatic, and hydrologic context of this extreme event. Nearly 100 people in-person and over 200 online attended the briefing, which also featured **Klaus Wolter** along with Martin Hoerling and Kelly Mahoney of the NOAA Earth Systems Research Laboratory's Physical Sciences Division and Nolan Doesken of the Colorado Climate Center at Colorado State University.

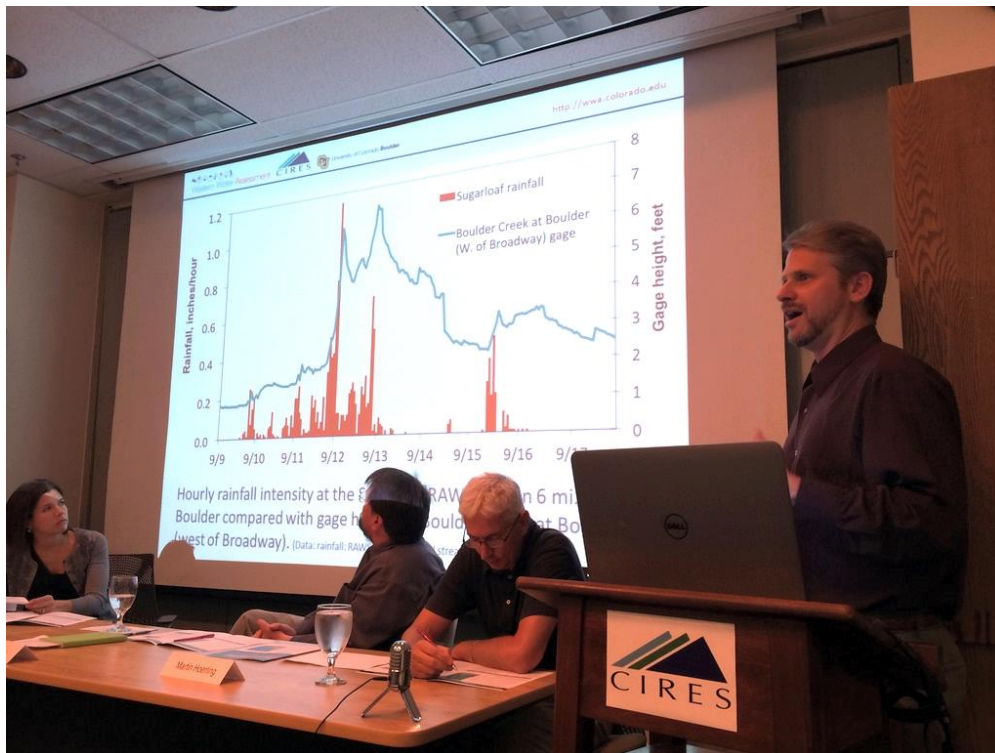


Figure 1. WWA's Jeff Lukas and Klaus Wolter join other colleagues in presenting meteorological, climatic, and hydrologic information about the Colorado Front Range Flooding of 2013 to a public audience.

Informing Water Managers About New Climate Projections

Imtiaz Rangwala has done extensive analysis of the differences between the projected climate in the Coupled Model Intercomparison Project, Phase 3 (CMIP3) and the newer set of model runs (CMIP5) for the Upper Colorado River Basin and the state of Colorado. Selected results of this analysis were presented at a variety of stakeholder forums, including the Upper Colorado River Basin Water Conference in November 2013, during a webinar held by the Carpe Diem West Academy, and at a WWA-organized meeting of the Front Range Climate Change Group (see below). Of particular interest to water management stakeholders were changes in projections of future precipitation in basins in western Colorado that feed into the Colorado River.

Media and Stakeholder Outreach on the Energy-Water Nexus

In addition to publishing several academic papers on the topic, **Kristen Averyt** engaged both decision makers and the public in numerous efforts intended to promote understanding of the effects of energy



production on water supplies. These efforts included filming a [video](#) with the University of Colorado Boulder's Office for University Outreach, being [interviewed on Colorado Public Radio](#), and co-presenting a [webinar](#) hosted by the Association of Metropolitan Water Agencies.

Describing Research Results to Utility CFOs

In March 2014, **Doug Kenney** co-hosted a workshop of water utility Chief Financial Officers (and related staff) examining water utility revenue volatility associated with climate events and other stressors affecting water demand and deliveries. This "CFO Connect Water Utilities" was held in cooperation with Ceres and the Water Efficiency Foundation and incorporated information from Kenney's 2014 paper in the *Journal of the American Water Works Association* entitled "Understanding Utility Disincentives to Water Conservation as a Means of Adapting to Climate Change Pressures."

Promoting Literacy Across Climate Topics

Eric Gordon, Jeff Lukas, Imtiaz Rangwala, Joe Barsugli, Lisa Dilling, and Kristen Averyt convened a series of climate literacy workshops for the Front Range Climate Change Group, an informal gathering of municipal water utility managers from Colorado's Front Range. Topics covered included updated (CMIP5) projections of precipitation in the Upper Colorado River Basin and relevant uncertainties, the effects of wildfire on soils and erosion into reservoirs, and communication of climate change information to the public.

Narrative Examples of Decisions Relevant to WWA Work

Salt Lake City: Using Climate Sensitivity Results in Operations and Planning

Salt Lake City Public Utilities (SLCDPU) worked with **Tim Bardsley** and other research partners to develop a study of the climate sensitivity of their water supplies. Rather than informing a specific decision, SLCDPU has used the study to inform all of their operations and planning—in other words, they have "mainstreamed" the information into their work, to use a term from climate adaptation practice. For more information on how SLCDPU's Laura Briefer is using the climate sensitivity study in her decision making and looking towards future collaborations with WWA, see the "Decision Maker Take 5" at <http://www.climate.gov/news-features/decision-makers-take-5/laura-briefer-talks-about-preparing-salt-lake-city's-water>.

The Nature Conservancy: Using WWA's Climate Guidance to Select Restoration Targets

Imtiaz Rangwala has been working directly with The Nature Conservancy (TNC) on conservation projects in Colorado's Gunnison River Basin. As part of these efforts, he has provided guidance derived from climate projections regarding the future viability of wet meadows critical to sage grouse habitat in the basin. Using this information, TNC and its partners have made decisions regarding the specific location of wet meadow restoration projects (Figure 2).



Figure 2. WWA's Imtiaz Rangwala (far left) joins others from The Nature Conservancy-led restoration efforts. Rangwala's climate projection guidance aided in the selection of restoration projects.

Navajo Nation: Considering WWA Climate Report in Adaptation Planning

In consultation with the Navajo Nation and in conjunction with the National Integrated Drought Information System (NIDIS) and the Getches-Wilkinson Center for Natural Resources, Energy, and the Environment, **Julie Nania** and **Karen Cozzetto** developed a report entitled "Considerations for Climate Change and Variability Adaptation on the Navajo Nation." This report provides a synthesis of climate-related information intended to be used for adaptation planning by the Navajo Nation. Along with information on potential impacts across a variety of sectors, Cozzetto and Nania's report includes guidance on developing and implementing adaptation planning processes. The Navajo Nation is currently reviewing this information as it determines how to proceed with climate adaptation efforts.



WWA 2013-2014 Publication Highlights

Averyt, K., J. Meldrum, P. Caldwell, G. Sun, S. McNulty, A. Huber-Lee, and N. Madden (2013). Sectoral contributions to surface water stress in the coterminous United States. *Environmental Research Letters*, Vol. 8, No. 3, doi: 10.1088/1748-9326/8/3/035046.

Bardsley, T., A. Wood, M. Hobbins, T. Kirkham, L. Briefer, J. Niermeyer, and S. Burian (2013). Planning for an Uncertain Future: Climate Change Sensitivity Assessment toward Adaptation Planning for Public Water Supply. *Earth Interactions*, Vol. 17, Issue 23, 1-26, October, doi: 10.1175/2012EI000501.1.

Bryant, A., T. H. Painter, J. S. Deems, and S. M. Bender (2013). Impact of dust radiative forcing in snow on accuracy of operational runoff prediction in the Upper Colorado River Basin. *Geophysical Research Letters*, Vol. 40, 3945-3949, doi:10.1002/grl.50773.

Cozzetto, K., K. Chief, K. Dittmer, M. Brubaker, R. Gough, K. Souza, F. Ettawageshik, S. Wotkyns, S. Opitz-Stapleton, S. Duren, and P. Chavan (2013). Climate change impacts on the water resources of American Indians and Alaska Natives in the US. *Climatic Change*, Vol. 120, Issue 3, 569-584.

Dilling, L. and R. Romsdahl (2013). Promoting Adaptation Success in Natural Resource Management Through Decision Support: Lessons from the Great Plains and Rocky Mountain Regions. In: S. Moser and M. Boykoff (eds.), *Successful Adaptation to Climate Change*, Routledge, pp. 180-185.

Vano, J. A., B. Udall, D. R. Cayan, J. T. Overpeck, L. D. Brekke, T. Das, H. C. Hartmann, H. G. Hidalgo, M. Hoerling, G. J. McCabe, K. Morino, R. S. Webb, K. Werner, and D. P. Lettenmaier (2013). Understanding Uncertainties in Future Colorado River Streamflow. *Bulletin of the American Meteorological Society*, doi: 10.1175/BAMS-D-12-00228.1.

WWA Metrics of Success

WWA is in the process of developing a new strategic plan. As part of this effort, we are revising the metrics used by the program to evaluate outputs and outcomes. Generally speaking, however, our new metrics of success will fall into three broad categories: knowledge production, learning and engagement, and knowledge networks. Likely outcomes to be assessed include changes in understanding, expansion of the knowledge network, resources conserved/saved, resources lost, money saved or lost, decisions or policies made, and new relationships forged.

Knowledge Production: Metrics in this category will be used to quantify and characterize the kinds of outputs we produce, their salience and credibility, the impacts our outputs have according to standard bibliometric measures, the degree to which the outputs reflect interdisciplinary scholarship, and the degree to which they integrate physical/social/natural sciences. Metrics will also characterize the spatial and temporal scale of the problem researched and how the outputs are intended to contribute in the decision process (e.g. from problem identification to policy implementation).



Learning and Engagement: Metrics in this category will be used to evaluate the ways in which knowledge outputs are produced, such as the degree to which intended users help to shape the research agenda, as well as how effectively WWA responds to users' expressed needs. Metrics will also capture the different ways that WWA conducts outreach and education to the public and other researchers. Other metrics will attempt to characterize WWA's role as a trusted source of information and its role in creating and leveraging social capital.

Knowledge Networks: Metrics in this category will characterize the scope of and change in WWA's knowledge network, which includes WWA researchers, other RISA researchers, external researchers, decision makers, and other stakeholders.



WWA 2013-2014 Project Reports

New Projects

Weber Basin Climate Sensitivity Analysis

Primary Investigator(s): T. Bardsley

Stakeholders: Weber Basin Water Conservancy District, Utah Division of Water Resources

Partners: D. Rosenberg (Utah State University), M. Bekker (Brigham Young University), A. Wood (NCAR), M. Hobbins (NOAA ESRL PSD), D. Cole (Utah Div. of Water Resources), T. Adams (Utah Div. of Water Resources), C. Hasenyager (Utah Div. of Water Resources), S. McGettigan (Utah Div. of Water Resources), J. Lhotak (NOAA NWS CBRFC), C. Peterson (NOAA NWS CBRFC)

Exploring climate change impacts on water supplies from the Weber River Basin.

This project came from a request by Weber Basin Water Conservancy district to explore climate change impacts to the Weber River water supply in collaboration with the Utah Division of Water Resources (UTDWR). UTDWR has developed a water supply model for the Weber River, which has been re-coded from the original Fortran to integrate into the Water Evaluation And Planning (WEAP) model by Utah State University (USU). The goal of the project is to develop relevant and defensible climate change scenarios and climate perturbed hydrologies, using the CBRFC model and evaluate impacts to the current operations of the Weber River system. Recently published tree-ring reconstructed streamflows may also be evaluated to explore extreme drought conditions beyond those in the observed record. The model will facilitate the exploration of a variety of new management, infrastructure, or demand changes to retain a resilient system. Initial work has focused on evaluating climate change sensitivities across multiple flow points on the Weber river and addressing evapotranspiration and model calibration.

Deliverables: Presentation and report to Weber Basin Water Conservancy District forthcoming

Leveraged Funding: In-kind staff efforts from NOAA Colorado Basin River Forecast Center, Utah State University, Brigham Young University, National Center for Atmospheric Research, and NOAA Earth Systems Research Laboratory Physical Sciences Division

Climate Support for Wasatch Mountain Accord

Primary Investigator(s): T. Bardsley

Stakeholders: Wasatch Mountain Accord group (<http://www.mountainaccord.com>)

Partners: Utah State University, Brigham Young University, US Forest Service

Synthesis and provision of credible climate information to inform the future consensus-based efforts of the Wasatch Mountain Accord.

The Mountain Accord is a long-range planning effort focused on the future of the central Wasatch Mountains and canyons. The Accord will use a systems approach to collaboratively optimize future scenarios across four areas – transportation, environment, economy, and recreation. WWA has participated in the environment systems group as well as smaller working groups on climate and water to coordinate relevant and credible climate information to inform the planning process. Anticipated deliverables are a white paper on observed and projected climate conditions to provide background for the each systems working group. Additional relevant climate information will be provided on request.

Deliverables: White paper on climate conditions delivered to group

Update of Climate Change in Colorado

Primary Investigator(s): J. Lukas

Stakeholders: Colorado Water Conservation Board; water managers and planners across the state of Colorado

Partners: Colorado Water Conservation Board

Comprehensive synthesis of observed and projected climate co-produced directly with the Colorado Water Conservation Board.

WWA is comprehensively updating and expanding their well-received 2008 *Climate Change in Colorado* report, also co-produced by WWA and the CWCB. The report synthesizes the best available climate science relevant to the state's water resources. Like the original, the updated report covers the observed climate patterns and trends in Colorado, a primer on climate models, linking observed state trends with global changes, projections of future climate and hydrology, and guidance on using this information in planning and management. Several dozen stakeholders at the local, state, and federal levels reviewed or contributed to the updated report. One key area of updating was using the new CMIP5 global climate model output; for Colorado, CMIP5 shows a modest shift towards wetter projected precipitation outcomes compared to



the previous CMIP3 models. This presented a challenge: acknowledging the resulting shift in ensemble-average modeled runoff, while reaffirming the need to prepare for a broad range of hydrologic outcomes.

Deliverables: Final report expected to be released in summer 2014

Leveraged Funding: \$45,000 from Colorado Water Conservation Board

Rapid Response to the 2013 Colorado Front Range Flooding

Primary Investigator(s): J. Lukas, K. Wolter

Partners: M. Hoerling (NOAA ESRL PSD), K. Mahoney (NOAA ESRL PSD), N. Doesken (Colorado Climate Center)

Rapid analysis and synthesis of meteorological and hydrological conditions that led to the September 2013 flooding along Colorado's Front Range.

The September 2013 flooding along Colorado's Front Range demonstrated the capacity of WWA to respond rapidly to science information needs about an extreme climate event—one that personally impacted many on its team. The core deliverable was a four-page preliminary assessment that explained the large-scale weather patterns responsible for the rains, compared the precipitation and flooding to historic events, and discussed potential linkages to climate change. Just ten days after the rains ended, WWA released the assessment at a public briefing and panel discussion in the CIRES Auditorium, attended by 100 people onsite, including local and national media, and another 200 online. Feedback from water resource managers and other decision makers confirmed that the assessment provided useful and relevant information on this destructive event. The report was later reprinted in a slightly different form in Colorado Water, the magazine of the CSU Colorado Water Institute, which has a circulation of over 4,000 people. To follow up, WWA is planning a "one year later" briefing and panel discussion to highlight new research on the meteorology, hydrology, and climate attribution of the floods, to be convened in fall 2014.

Deliverables: Four-page assessment, seminar and webinar for public audience, multiple invited presentations

Leveraged Funding: In-kind contributions from NOAA ESRL PSD, Colorado Climate Center

Regional 2013 Drought Briefing

Primary Investigator(s): J. Lukas, L. Darby (NIDIS)

Stakeholders: Regional decision makers (water, agriculture, others) and policy makers

Partners: National Integrated Drought Information System

Real-time assessment of the development and use of stakeholder-oriented tree-ring paleohydrology research for water resource planning on the Wasatch Front.

The purpose of this project was to produce a concise, high-level briefing on rapidly expanding and intensifying drought conditions in June 2013 in the Upper Colorado River Basin and New Mexico. The briefing used text and graphics to convey recent precipitation and current drought conditions, agricultural impacts, runoff conditions and reservoir levels, and wildfire impacts. The briefing was similar to one co-produced by WWA and NIDIS in July 2012, and was disseminated through the WWA website and mail list, and through the NIDIS website (drought.gov). With a now well-established model, a new briefing could be quickly developed as future drought conditions call for it.

Deliverables: Two-page drought synthesis distributed to regional stakeholders

High-Resolution Meteorological and Hydrologic Data Extension to Trans-Boundary Basins in the Conterminous U.S., Southern Canada and Northern Mexico

Primary Investigator(s): B. Livneh

Partners: U.S. Bureau of Reclamation

Using hydrologic modeling to examine the influence of dust deposition and climate change on snowmelt, runoff timing, and volume in the Colorado River Basin.

The purpose of this project is to address questions related to Reclamation's needs to improve existing methods of extreme precipitation estimation, as well as improved understanding of appropriate applications of model and reanalysis-based extreme precipitation data. This will involve extending the data development and model application methods featured in Livneh et al. (2013) to expand geographic coverage from contiguous U.S. to the North American Land Data Assimilation (NLDAS) domain. PI will document data and model development and demonstrate utility through evaluation of spatiotemporal statistics for temperature and precipitation, i.e. exceedance probabilities, frequency of extremes, and a comparison of drought characteristics relative to other dataset(s).



Deliverables: 1/16 degree gridded fields of daily precipitation, wind, and minimum and maximum temperatures over the NLDAS domain for the period 1950 – 2011; a daily hydrologically consistent dataset over NLDAS domain; documentation of data and model extensions

Leveraged Funding: \$40,000 from U.S. Bureau of Reclamation

Colorado Climate Change Vulnerability Study

Primary Investigator(s): E. Gordon

Partners: D. Ojima (Colorado State University)

Overview of key climate-related vulnerabilities facing several sectors in the State of Colorado.

During its 2013 session, the Colorado Legislature passed HB 13-1293, which declared that “climate change presents serious, diverse, and ongoing issues for the state’s people, economy, and environment.” Among other provisions, the bill required a person appointed by the Governor to submit an annual report to a number of committees within the legislature “on climate change issues generally, the current climate action plan...and the specific ways in which climate change affects the state.” Multiple state agencies, including the Colorado Energy Office, the Colorado Department of Public Health and the Environment, and the Colorado Water Conservation Board are leading efforts to respond to this legislation and to meet the challenges of climate change in the state. To help meet this requirement, the Colorado Energy Office commissioned the University of Colorado Boulder (through the Western Water Assessment) and Colorado State University to complete a study providing an overview of the key vulnerabilities that climate change and climate vulnerability will pose for Colorado's economy and resources.

Deliverables: Final *Colorado Climate Change Vulnerability Study* report expected in Summer 2014

Leveraged Funding: \$73,500 from Colorado Energy Office

Evaluation of NIDIS Upper Colorado River Basin Drought Early Warning System

Primary Investigator(s): E. McNie

Stakeholder: National Integrated Drought Information System

Evaluation of utility of NIDIS’s first drought early warning system (DEWS) to provide lessons for other regional DEWS efforts.

This project entailed the development a comprehensive evaluation for the National Integrated Drought Information System Upper Colorado River Basin Drought Early Warning System (UCRB DEWS). PI completed scoping interviews with UCRB DEWS personnel, semi-structured interviews with sample of UCRB DEWS stakeholders, archival research, collection of analytics of webinar and web page use, and development of a comprehensive online survey of DEWS services and products. The survey was designed to be transferrable to other DEWS locations and programs. In process of finalizing first draft of evaluation report. PI also used this project for ongoing consultation on the development of a ‘Mid-Level Climate Services Evaluation Tool’ with the International Research Institute’s Climate and Society Program at Columbia University. Beta-tested this ‘mid-level tool’ with the evaluation project conducted for the National Integrated Drought Information System Upper Colorado River Drought Early Warning System. Feedback has been provided to IRI and collaboration continues with group to revise the tool.

Deliverables: Report on evaluation of UCRB DEWS expected in 2014

Evaluation of Western Water Assessment’s “Utah Model”

Primary Investigator(s): E. McNie

Stakeholders: WWA, NOAA RISA Program

Assessment of the preliminary results of WWA’s effort to expand its presence in Utah.

This project examines what WWA calls the ‘Utah Model’ (directly hiring a boundary professional to expand WWA’s geographic reach) and how this alternative approach to the traditional university-based model expanded WWA’s network and provided climate-related decision-support activities in novel ways. As with many RISA activities, the Utah Model is a work in progress, so findings are rather limited at this time. Furthermore, our sample size of stakeholders is very small so this case study should be viewed as the starting point for discussions about the role of RISAs within a broader decision-support community. Furthermore, our sample size of stakeholders is very small so this case study should be viewed as the starting point for discussions about the role of RISAs within a broader decision-support community, and not be construed as conclusive.

Deliverables: Report on “WWA’s The Utah Model” completed, to be posted on WWA website

Typology of Useful Science Approaches



Primary Investigator(s): E. McNie, D. Sarewitz (Arizona State University)

Stakeholder: Science policy community

Development of a typology of research approaches related to user-inspired science.

In collaboration with the Center for Science and Policy Outcomes at Arizona State University, PI is developing a typology of research approaches of user-inspired research in order to help shape research agendas to lead to the production of useful information for decision makers. The typology currently under development uses over 20 different variables in four categories to characterize knowledge, learning and engagement, power and politics, and organization design of research approaches to achieve different goals. This effort is supported financially by the Packard Foundation.

Deliverables: Final report expected in 2014

Leveraged Funding: \$5,000 from Packard Foundation

Media Treatment of “Climate Change” in Shaping Colorado River Problems and Solutions

Primary Investigator(s): D. Kenney

Analysis of media coverage of Colorado River issues shows relatively little discussion of climate change since 2000.

The project reviewed newspaper coverage of Colorado River issues from 2000 to 2013 in order to identify the extent to which climate change is identified as a contributing factor to ongoing water shortages and, similarly, is a challenge to be addressed going forward. Two clear themes emerged from the analysis: (1) climate change is largely absent from the media coverage (mentioned in less than 10% of articles), although there was a slight uptick in the last few years of the study period; (2) to the extent that climate issues are mentioned, “acute drought” or “persistent drought” dominate, reflecting an ongoing preference amongst water managers and the media to view current issues as a temporary phenomenon rather than as a fundamental shift in regional hydroclimatology. These findings suggest an ongoing need for education about the existence and significance of climate change in the basin.

Deliverables: Final white paper completed in spring 2014

Exploring Regional Climate Service Collaborations

Primary Investigator(s): K. Averyt

Stakeholders: Climate services community

Partners: J. Morissette (NC CSC), D. Ojima (NC CSC), L. Joyce (USDA Northern Plains Regional Hub), J. Derner (USDA Northern Plains Regional Hub)

Analyzing and reporting on collaborations among three regional climate service entities to provide lessons learned.

One challenge, and opportunity, facing WWA and the RISA program is the increasing interest in delivering climate services by Federal agencies other than NOAA. While the increased investment is encouraging, it creates some challenges, and questions emerging from leadership in the Executive Branch seeking definition of these different entities. Thus far, there has been difficulty addressing this question because of the highly adaptive nature of regional climate services. WWA, and others, are faced with navigating the field of federal authorizations, regional priorities, scientific expertise, budgets, and scientific expertise on the teams leading separate Federally funded climate service efforts. However, these challenging circumstances have given rise to success stories that highlight why climate services should be conceived, developed and focused on regional priorities. WWA is collaborating with the leaders of the North Central Climate Science Center and the Northern Plains USDA Hub to craft a paper outlining how collaboration among these entities has worked in the past, how it is working now, and how future partnerships will work. The paper will demonstrate how the allowance of an adaptive framework is an important mechanism for ensuring the most efficient synergies among these entities as they strive to collaborate with decisionmakers.

Deliverables: Publication in prep

Climate Science Support for the North Central Climate Science Center

Primary Investigator(s): K. Averyt, J. Barsugli

Stakeholders: Various in NC CSC stakeholder community

Partners: J. Morissette (NC CSC), D. Ojima (NC CSC),

Providing climate science support for the DOI North Central Climate Science Center.

Western Water Assessment is a partner with the North Central Climate Science Center (NCCSC), based at Colorado State University. Averyt serves as the CU Boulder representative to the University Consortia Team. The NCCSC is framing its research agenda and strategic in a framework termed ReVAMP (Resource for Vulnerability Assessment, Adaptation and Mitigation Planning). The implementation plan has three



parts: Climate Science, Impacts, and Vulnerability/Adaptation. Each has a science lead, and PI Barsugli serves as the lead for the Climate Science part of this effort. The NCCSC is leveraging the climate, hydrology and communication expertise within the WWA team to collaborate with their socio-ecological experts. WWA has funding from the NCCSC for a 2-year post doc who will focus on evapotranspiration questions relevant to both WWA and NCCSC interests.

Deliverables: Postdoc hire completed; direct climate science support for NC CSC projects; other deliverables to be determined.

Drought Dashboards

Primary Investigator(s): W. Travis

Stakeholder: National Integrated Drought Information System

Prototyping new methods for visualizing socioeconomic indicators of drought.

Building on previous WWA work to identify appropriate socioeconomic indicators of drought, PIs sought in this project to explore visualization methods. The idea of creating “drought dashboards” is a prototyping effort aimed at developing the concepts, data, skills, tools, and prototypes for drought impact assessment via rapid analytics and dashboards. The development has been recorded a white paper and the dashboard made available online at <http://public.tableausoftware.com/views/DroughtDashboard/AffectedPopulation>. Ongoing discussions will explore the utility of this approach for NIDIS.

Deliverables: Drought dashboard prototype available at <http://public.tableausoftware.com/views/DroughtDashboard/AffectedPopulation>; WWA White Paper “Tracking Socioeconomic Impacts of Drought with Rapid Analytics and Dashboards” available at <http://www.colorado.edu/publications/reports/2013.01.pdf>.

Ongoing and Completed Projects

Climate Adaptation Guidance for Salt Lake City Public Utilities

Primary Investigator(s): T. Bardsley

Stakeholder: Salt Lake City Department of Public Utilities

Partners: A. Wood (NCAR), L. Briefer (SLCPUD), J. Niermeyer (SLCPUD), M. Hobbins (NOAA ESRL PSD), S. Burian (University of Utah), E. Goharian (University of Utah), C. Strong (University of Utah), P. Stoker (University of Utah), J. Lhotak (NOAA CBRFC), C. Peterson (NOAA CBRFC)

Working with the Salt Lake City Department of Public Utilities (SLCPUD) to help them assess the challenges that climate change presents to their water supply system.

WWA’s Tim Bardsley has spearheaded a climate change assessment and adaptation planning effort for the Salt Lake City Department of Public Utilities. The results of this first phase of work, consisting of a water supply climate sensitivity analysis, was published as “Planning for an Uncertain Future: Climate Change Sensitivity Assessment towards Adaptation Planning for Public Water Supply” in a special edition of *Earth Interactions*. This paper produced numerous media hits and was cited as a prime example of local-level adaptation work by the White House Office of Science and Technology Policy. Ongoing efforts in this project include a pilot study on one of Salt Lake City’s watershed creeks, where a reservoir systems planning model has been developed. The model has recently been expanded to include the full water supply system. This systems model is currently being incorporated into an integrated water planning model. The planning model will facilitate more comprehensive assessments of changes in system reliability are being evaluated in combination with future water demand, supply, infrastructure, and management scenarios. To add to available information on climate impacts to water supplies, Bardsley will work with colleagues to integrate soon-to-be-available high-resolution dynamically downscaled climate projections, test an expanded integrated water planning model, and develop more advanced water supply and demand scenarios to evaluate a range of possible future impacts to water supply to assist in defining low-regrets management strategies.

Deliverables: 2013 publication of article in *Earth Interactions*; multiple stakeholder presentations; information directly transferred to SLCPUD

Leveraged Funding: In-kind staff efforts from NOAA Colorado Basin River Forecast Center, University of Utah, National Center for Atmospheric Research, and NOAA Earth Systems Research Laboratory Physical Sciences Division

Project Evaluation for Stakeholder-Oriented Paleohydrology

Primary Investigator(s): T. Bardsley, J. Lukas

Stakeholders: Water managers across the Wasatch Front urban corridor



Partners: Wasatch Dendroclimatology Research Group (Utah State University)

Real-time assessment of the development and use of stakeholder-oriented tree-ring paleohydrology research for water resource planning on the Wasatch Front.

Real-time longitudinal investigation of the process by which new dendrochronological information is incorporated into water management across the Wasatch Front. A research team led by the Wasatch Dendroclimatology Research Group (WADR) at Utah State University is in the process of developing proxy hydrology records from tree rings for Wasatch Front creeks in order to provide water managers with a longer period of record to aid in planning. The WADR group is carrying out their technical work and stakeholder interactions following an earlier model developed by Connie Woodhouse and Jeff Lukas in Colorado. WWA intends to follow this effort through a real-time, longitudinal tracking of the process and interactions between the WADR research team and water managers to gain insights into the challenges, capabilities, and limitations in the incorporation of tree-ring data into planning processes. Pls will also compare the research-stakeholder interactions on the Wasatch Front with those that were documented in Colorado in Rice et al. (2009) to see if any cross-regional differences can be observed and then examined. Ultimately, this project is intended to improve the co-production of knowledge between researchers and decision makers in water resources. Note little progress in this reporting period for WWA; pace of project is determined by progress of WADR group and stakeholder participation, both of which have caused the project to move slowly.

Deliverables: Article or report evaluating paleohydrology effort expected in 2014 or when appropriate based on project progress.

Snowmelt Perturbations and Water Supply Forecast Errors

Primary Investigator(s): J. Deems, B. Livneh, C. Wessman, N. Molotch, J. Barsugli, K. Wolter

Stakeholders: NOAA NWS Colorado Basin River Forecast Center, water managers using CBRFC streamflow forecasts

Partners: NIDIS, NOAA NWS Colorado Basin River Forecast Center, Institute for Arctic and Alpine Research (Univ. of Colorado)

A collaborative effort among WWA hydrologists, ecologists, weather and climate experts, and operational forecasters at the NOAA Colorado Basin River Forecast Center in an effort to use a suite of modeling and observation techniques to better understand drivers of snow accumulation and melt in the Upper Colorado River Basin with the ultimate goal of improving CBRFC forecasts.

Since 2002, the headwaters of the Colorado River and nearby basins have experienced extensive changes in land cover, raising questions about streamflow and forecast accuracy. Widespread tree mortality from bark beetle infestation has taken place across a range of forest types, elevation, and latitude. Extent and severity of forest structure alteration have been observed through a combination of aerial survey satellite remote-sensing, and in situ measurements. Additional perturbations have resulted from deposition of dust from regional dry-land sources on mountain snowpacks that strongly alter the snow surface albedo, driving earlier and faster snowmelt runoff. These perturbations likely result in abnormalities between the historical relationships between the quantity of snowfall and the resulting streamflow volume, which provide the basis for operational water supply forecasts. This project sought identify the effect of these perturbations on streamflow generation, providing water resource managers guidance as to how operational water supply forecast models may need to be augmented to account for changes in runoff production. Pls drove the Distributed Hydrology and Vegetation Model (DHSVM) with observed meteorology, distributed satellite-based snowpack information, time-varying maps of leaf area index and forest properties to emulate bark beetle impacts, and parameterizations of snow albedo based on observations of dust forcing. Results from beetle-killed canopy alteration suggest slightly greater snow accumulation as a result of less interception and reduced canopy sublimation, contributing to overall increases in annual water yield on the order of 10 %. However, understory regeneration roughly halves the changes in water yield. Contrasted against a purely observational estimate of runoff efficiency change with cumulative forest mortality, the results suggest comparable sensitivities; however, positive water yield changes are not statistically significant. The primary hydrologic impact of dust-on-snow forcing is an increased rate of snowmelt associated with more extreme dust deposition, producing earlier peak streamflow rates for snowmelt-dominated catchments on the order of 1 – 3 weeks. Future work based off of this project may focus on methods to ingest spatial hydrologic information into the NOAA CBRFC streamflow forecasting processes to improve forecast model representation of these perturbations.

Deliverables: Livneh B., J.S. Deems., D. Schneider, J. Barsugli, and N.P. Molotch (2014), Filling in the Gaps: Inferring Spatially Distributed Precipitation from Gauge Observations over Complex Terrain. *Water Resources Research*, in review; Livneh B., J.S. Deems, B. Buma, J.J. Barsugli, D. Schneider, N.P. Molotch, K. Wolter, and C.A. Wessman, 2014: Catchment Response to Bark Beetle Outbreak in the Upper Colorado River Basin, *Journal of Geophysical Research* (in preparation). Multiple efforts to integrate research findings into CBRFC operations.

Impacts of Coupled Climate Change and Dust Deposition on Water Resources in the Colorado River Basin

Primary Investigator(s): J. Deems

Stakeholders: Water managers and planners throughout the Upper Colorado River Basin

Partners: C. Landry (Center for Snow and Avalanche Studies), T. Painter (Jet Propulsion Laboratory)

Using hydrologic modeling to examine the influence of dust deposition and climate change on snowmelt, runoff timing, and volume in the Colorado River Basin.

This project examined hydrologic impacts of dust radiative forcing on snowmelt and climate change in the Upper Colorado River Basin (UCRB).



Moderate dust deposition, such as observed in 2005-2008, shifts peak flow at Lees Ferry earlier in the year by approximately 2 weeks, and the 1-month longer snow-free season reduces total flow volume by order 5% relative to pre-settlement conditions in the 1800s. Extreme dust deposition, such as observed in 2009 and 2010, induces an extra 2-week shift in flow timing and an additional 1% loss in flow volume. Simulations of climate forcing of temperature and precipitation induce losses of 10 to 20% of flow and runoff timing shifts of 10-20 days relative to current climate, moderate dust conditions. In combination, dust on snow continues to exert a strong influence on flow timing even under severe climate perturbation, while future flow reductions are dominated by climate change-driven reductions in snow accumulation. Ongoing work leveraged through the NASA Interdisciplinary Sciences program seeks to resolve spatial variation in dust forcing across the UCRB, to characterize individual sub-basin vulnerability to dust forcing, and to identify dust sources and opportunities for remediation.

Deliverables: Deems, J. S., Painter, T. H., Barsugli, J. J., Belnap, J. and Udall, B.: Combined impacts of current and future dust deposition and regional warming on Colorado River Basin snow dynamics and hydrology, *Hydrol. Earth Syst. Sci.*, 17(11), 4401–4413, doi:10.5194/hess-17-4401-2013, 2013.

Leveraged Funding: \$70,000 from NASA Interdisciplinary Sciences

Drivers of Adaptation: A Comparative Analysis of Local Decision Making in the American West

Primary Investigator(s): L. Dilling, K. Andersson

Multi-year effort to systematically investigate reasons why local decision makers in cities and large towns in Colorado, Utah, and Wyoming respond to weather and climate-related risk and hazards, such as blizzards, tornadoes, and floods.

As a complement to studies that examine barriers to adaptation, PIs conducted a study of the drivers that lead to planning for and responding to weather and climate-related hazards at the municipal scale as a proxy for understanding what might drive adaptive behavior towards climate change. Municipalities in Colorado, Utah, and Wyoming were chosen for the study, and researchers conducted face-to-face and phone interviews with multiple key informants in a randomly selected sample of 60 municipalities with populations over 10,000. The results suggest that municipalities do exhibit a wide variety of responses to weather and climate risk, despite similar levels of exposure in some cases. The reasons for these different responses are complex, and actions are not explainable by a single factor such as economic status or population size. Additional factors such as experiencing previous events, municipal champions, cultural values, and differences at the state level were found to have some influence, but individually these factors do not explain more than 5-15% of the variation in the municipal responses. These results have been drafted for publication, with submission expected in early summer of 2014. Following the initial interviews, the researchers conducted in-depth case studies with six of the municipalities to better understand the combinatorial relationship of the potential explanatory factors. Analysis of the case studies is currently being completed and will be submitted for publication.

Deliverables: Peer-reviewed publication to be submitted in 2014

Analysis of Use of Information by Stakeholders of the Colorado Basin River Forecast Center

Primary Investigator(s): L. Dilling, R. Klein

Stakeholder: NOAA NWS Colorado Basin River Forecast Center

Effort to understand the flow of forecast information to stakeholders of the NOAA Colorado Basin River Forecast Center.

The Colorado Basin River Forecast Center (CBRFC) generates forecasts across the Colorado Basin and Utah including daily streamflow forecasts, long lead peak flow forecasts and water supply forecasts. Decision makers such as Denver Water, the Bureau of Reclamation, the Central Arizona Project, and the Colorado River District are some of the CBRFC stakeholders who use or potentially might use these forecasts. Previous research has found, however, that unless reliability and/or quality are threatened, water management agencies have little incentive to use forecasts (especially ensemble forecasts), and that forecast use correlates more with perceived risk than with forecast skill and reliability. A series of workshops with CBRFC stakeholders (facilitated through a previous WWA-CLIMAS project) assessed individual decisionmaking processes in order to see how stakeholders processed visual representations of streamflow data and forecasts and then used this information in decisionmaking. One of the conclusions from the workshops was that a better understanding of the decision making process was needed (Werner et al. 2011). The Deems et al. "Snowmelt Perturbations" project falls within the research and operations part of the framework in that it is working to improve tools such as CBRFC forecasts. This project will augment the snowmelt research by obtaining a better understanding of both the CBRFC stakeholder decision making process as well as how WWA research can feed into this process. We will provide basic data on the stakeholders of the CBRFC, their climate-related decision making contexts, and the role that information does and could play. We also will analyze the potential for the WWA snowpack physical science research to be usable in the CBRFC context and how such information can help stakeholders make better decisions. PIs are preparing a summary and analysis of the interviews which will be integrated with the survey results into a final white paper that will be shared with CBRFC and posted on the WWA website.

Deliverables: Initial survey results presented to CBRFC; White paper to be completed in 2014



Water, Energy, and Climate Change: Freshwater Use by Power Plants in the United States

Primary Investigator(s): K. Averyt, J. Meldrum, I. Rangwala

Stakeholders: Public utility commissions, USGS, DOE, water resource planners, electric utilities

Partners: S. Tellinghuisen (Western Resource Advocates), R. Newmark (NREL), J. Macknick (NREL), D. Yates (NCAR)

Understanding the impacts of electricity generation on freshwater resources in a warming world.

PIs have been actively publishing research exploring critical questions at the nexus between energy and water. Particular attention has been paid to the impacts of shifts in water resources on national and regional electricity generation. The research completed in 2012-13, and published through 2013 explores this issue on the national scale, in the ACT Basin, and in the greater Colorado River Basin. Further work showed that although power plants, on average, are not contributing to water stress, building a single thermoelectric plant can directly impact local water availability for other uses in a way that establishing a single farm cannot. Therefore, it is important to consider sensitivity of water resources when siting power plants. Currently, WWA is engaged in a project through the Joint Institute for Strategic Energy Analysis (JISEA), where PIs are mapping future electricity demands, future water demands, onto water availability as defined by 3 different climate scenarios derived from CMIP5 output. A paper is forthcoming and will be submitted in Summer/Fall 2014.

Deliverables: Averyt, K, J Macknick, J Rogers, N Madden, J Fisher, J Meldrum and R Newmark (2013), Water use for electricity in the United States: an analysis of reported and calculated water use information for 2008. *Environ. Res. Lett.*, 8 (1), issn: 1748-9326; Averyt, K, J Meldrum, P Caldwell, G Sun, S McNulty, A Huber-Lee and N Madden (2013), Sectoral contributions to surface water stress in the coterminous United States. *Environ. Res. Lett.*, 8 (3), issn: 1748-9326; Yates, D, J Meldrum and K Averyt (2013), The influence of future electricity mix alternatives on southwestern US water resources. *Environ. Res. Lett.*, 8 (4), issn: 1748-9326; Meldrum, J. R., K. B. Averyt, J. E. Macknick, R. L. Newmark, J. Rogers, N. Madden, and J. I. Fisher (2013), Sensitivities of Recent Electricity Generation Water Use Findings to Data Updates and Variability. , *American Society of Mechanical Engineers 2013 Power Conference*, Boston, Massachusetts, July 29–August 1, 2013, Art. No. POWER2013-98227; S. Cohen, J. Meldrum, K. Averyt, J. Macknick, I. Rangwala (in preparation) Sensitivity of powerplant development to different CMIP5 hydrologic projections.

Assessment of Climate Change in the Southwestern United States

Primary Investigator(s): K. Averyt, L. Dilling, W. Travis, E. Gordon, J. Lukas, K. Cozetto. A. Nacu-Schmidt, J. Barsugli, A. Ray, B. Rajagopalan, I. Rangwala, K. Wolter, B. Udall

Stakeholders: Many potential climate-sensitive decision makers across NCA Southwest region

Partners: CLIMAS RISA, CNAP RISA, others from across the region

Participating in the development of the Southwest Region Technical Input and other portions of the National Climate Assessment.

After several years of effort, the National Climate Assessment was released in early May 2014. WWA made significant contributions to the process. K. Averyt was a lead author for the energy-water-land chapter, and K. Cozetto was a contributing author for the tribal regions chapter in the National document. But prior to publication of the final document, WWA supported the inception, development, and publication of the Technical Input to the Southwest Region. Over a dozen authors from the WWA Team were coordinating lead authors and lead authors for the document. Others on the WWA Team also contributed to additional technical inputs. For future work, WWA plans to engage in the ongoing assessment concept. The team expects to dovetail efforts at the federal level with state-based assessments. In coordination with the RISA Program Office, and other RISAs, WWA expects to learn more about the future of ongoing assessment.

Deliverables: Co-authorship of 11 chapters in *Assessment of Climate Change in the Southwest United States: A Report Prepared for the National Climate Assessment*, edited by G. Garfin, A. Jardine, R. Merideth, M. Black, and S. LeRoy, 197–217. A report by the Southwest Climate Alliance. Washington, DC: Island Press.

Understanding Utility Disincentives to Urban Outdoor Water Conservation as a Means of Adapting to Climate Change Pressures

Primary Investigator(s): D. Kenney

Stakeholders: Municipal water managers and government officials responsible for establishing the administrative and financial framework within which municipal water management takes place

Partners: Ceres, Water Education Foundation

Investigation of how institutional incentives may affect the use of outdoor water conservation by water utilities as a climate adaptation strategy.

The project examined two constraints, or “disincentives,” that can preclude a municipal water agency from embracing demand management strategies as part of long-term climate change adaptation. The first, often described as “demand hardening,” is the concern that ongoing improvements in conservation remove the “slack” from a water system, thereby making it difficult to reduce further demand in the response to climate pressures or other stressors. Our research suggests this problem is more speculative than real at this time, and is a problem that can be addressed by ensuring that conserved water is primarily allocated to storage rather than as a baseline supply for new development.



The second issue is the water utility revenue instability that is associated with conservation, as reduced demands typically result in declining revenue streams for utilities. “Selling every drop” of water is good business for a utility, but is maladaptive from a climate standpoint. Removing this disincentive can require modifying the revenue model under which utilities operate, which is challenging in part because it involves changing rules that are beyond the control of the utilities themselves. In addition to a publication in a stakeholder-oriented journal, this project resulted in a March 2014 workshop with water utility Chief Financial Officers to explore and discuss these issues.

Deliverables: Kenney, Douglas S. 2014. Understanding Utility Disincentives to Water Conservation as a Means of Adapting to Climate Change Pressures. *Journal – American Water Works Association*, 106(1): 36-46, January; workshop with water utility CFOs in March 2014.

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

Primary Investigator(s): W. Travis, I. Rangwala, J. Barsugli, G. Garfin (CLIMAS), E. Gordon

Stakeholders: The Nature Conservancy, others participating in Gunnison Basin conservation efforts

Partners: The Nature Conservancy, DOI/USGS North Central Climate Science Center, CLIMAS RISA

Project funded by intra-RISA competition will provide an opportunity to pilot new efforts to integrate climate science into conservation adaptation efforts developed by The Nature Conservancy in the Southwest.

Collaboration with Leveraged Project: Southwest Colorado Social Ecological Climate Resilience: The experience of the project personnel in the core effort helped Travis and Rangwala become part of a separate but linked DOI North Central CSC-funded project. Rangwala has been the lead climatologist on this project, which entails a collaboration among the Nature Conservancy (TNC) and its partners in the Gunnison Basin, San Juan Mountains and the Four Corners regions. He has developed landscape-scale climate scenarios from the CMIP5 global climate models for the region. These will be used by an ecologist and a social scientist, in conjunction with Rangwala, to develop narrative scenarios of future climate and its impacts. Next, the project scientists, in a collaborative process with land managers, will use these narrative scenarios to develop robust adaptation strategies that could work across these climate futures for a particular time horizon. Rangwala is developing “target-specific” climate scenarios for different systems targets selected in the project. This information will be collaboratively produced by integrating the expert and local knowledge of a specific target with the larger scale climate projections. It is expected that development of such information would be more actionable for the user community. *Evaluate and improve methodologies for developing “actionable climate scenarios”:* Rangwala has been working with Barsugli, Travis, Clifford, Betsy Neely (TNC), Renee Rondeau (Colorado Natural Heritage), Erin Towler (NCAR), Teresa Chapman (TNC), Laurie Young and Carina Wyborn (U. Montana), among others, to evaluate and improve the approach for developing more effective and actionable climate scenarios for resource management and conservation. *Understanding local climate knowledge and its influence on decision making:* Clifford designed a survey to probe local knowledge of climate and stakeholder climate information needs for application during a summer 2013 fieldwork season. The survey was approved by the university’s IRB for human subjects, and administered by Clifford in the field during July-August, 2013. Twenty-six of the 28 interviews were transcribed in their entirety using “intelligent verbatim” protocol to maintain the rich quality of each interview and correctly capture participants’ opinions and insights, while dispensing with non-essential words. These documents ranged from 1297 to 4310 words per interview transcript. Transcribed interviews were entered into the qualitative coding software, NVivo, and coded according hypotheses, interview topics and assumed themes. The a priori codes were built around the hypothesized structure of climate features, benchmarks and processes, that we expected interviewees to use when explaining experienced climate.

Deliverables: Direct guidance to TNC and its partners; AGU poster; K. Clifford Master’s Thesis

Leveraged Funding: \$10,000 in travel and other support from TNC

Climate Change Preparedness Among Tribal Communities in the American West

Primary Investigator(s): K. Cozzetto, J. Nania

Stakeholders: Navajo Nation

Partners: NIDIS, CLIMAS

Delivering climate guidance for the Navajo Nation as part of an effort to build stakeholder relationships with native communities and understanding tribes’ needs for relevant climate information to prepare for climate change.

In consultation with the Navajo Nation and in conjunction with the National Integrated Drought Information System (NIDIS) and the Getches-Wilkinson Center for Natural Resources, Energy, and the Environment, WWA team members Julie Nania and Karen Cozzetto recently completed a report entitled “Considerations for Climate Change and Variability Adaptation on the Navajo Nation.” This report provides a synthesis of climate-related information intended to be used for adaptation planning by the Navajo Nation. Along with information on potential impacts across a variety of sectors, Cozzetto and Nania’s report includes an example adaptation planning and implementation process. The Navajo Nation is currently reviewing this information as it determines how to proceed with climate adaptation efforts.

Deliverables: WWA report *Considerations for Climate Change and Variability Adaptation on the Navajo Nation* available at http://www.colorado.edu/publications/reports/navajo_report4_9.pdf.



Decisionmaking Under Hydro-Climatic Uncertainty

Primary Investigator(s): W. Travis, M. Huisenga

Development of models and other tools capable of understanding how decision deal with hydro-climatic uncertainty in climate adaptation, including response to droughts.

This project seeks to develop and apply decision analysis to adaptation of climate-sensitive activities in the WWA region. It fits in between vulnerability assessments and empirical studies of adaptation, providing a modeling “test bed” to develop hypothesis and test hypotheses about how decision makers might respond to climate variation and change in specific resource management systems. Particular attention is given to adaptation decisions in response to extreme climate events. The project effort is guided by attention to decision analysis and decision support in the latest National Climate Assessment. A proposal to increase effort on the climate risk and adaptation decisions modeling work focused on the role of extreme events in climate decision-making was submitted to the Risk and Decision, Risk and Management Sciences (DRMS) division of NSF in January, 2013.

Deliverables: W.R Travis and M. Huisenga (2013) “The Effect of Rate of Change, Variability, and Extreme Events on the Pace of Adaptation to a Changing Climate.” *Climatic Change* 121: 209–222. DOI 10.1007/s10584-013-0876-3

Intermountain West Climate Dashboard

Primary Investigator(s): J. Lukas, E. Gordon, T. Bardsley, K. Wolter

Stakeholders: Water resources managers; anyone needing to monitor evolving weather, climate, and hydrologic conditions

Development of a new web resource providing updated regional climate information as soon as it is produced.

The Intermountain West Climate Dashboard made its debut in October 2012 as a prototype/replacement for the more staff-intensive yet less timely Intermountain West Climate Summary digest produced by WWA since 2005. It is a grid of 30 weather, climate and water information graphics that are automatically updated on the Dashboard as their providers update them. In the past year and a half, feedback from WWA stakeholders has indicated that the Dashboard is a very useful ‘one-stop shop’ for up-to-date climate and water information. And the creation of similar dashboards by other climate-service entities (e.g., Great Basin Climate Dashboard by WRCC and DRI/CNAP) is further confirmation of the effectiveness of this format. In the coming year, WWA plans to evaluate the Dashboard in the context of the increasingly similar product of the NIDIS Upper Colorado River Basin Drought Early Warning System (produced by the CSU Colorado Climate Center). The Intermountain West Climate Dashboard is at: <http://www.colorado.edu/climate/dashboard.html>.

Deliverables: Intermountain West Climate Dashboard web resource (<http://www.colorado.edu/climate/dashboard.html>)



APPENDIX A: List of 2013-2014 WWA Publications

Averyt, K., L. D. Brekke, D. E. Busch, L. Kaatz, L. Welling, and E. H. Hartge (2013). [Moving Forward with Imperfect Information](#). In Assessment of Climate Change in the Southwest United States: A Report Prepared for the National Climate Assessment, edited by G. Garfin, A. Jardine, R. Merideth, M. Black, and S. LeRoy, 436–461. A report by the Southwest Climate Alliance. Washington, DC: Island Press.

Averyt, K., J. Macknick, J. Rogers, N. Madden, J. Fisher, J. Meldrum, and R. Newmark (2013). [Water use for electricity in the United States: an analysis of reported and calculated water use information for 2008](#). Environmental Research Letters 8(1).

Averyt, K., J. Meldrum, P. Caldwell, G. Sun, S. McNulty, A. Huber-Lee, and N. Madden (2013). [Sectoral contributions to surface water stress in the coterminous United States](#). Environmental Research Letters, Vol. 8, No. 3, doi: 10.1088/1748-9326/8/3/035046.

Bardsley, T., A. Wood, M. Hobbins, T. Kirkham, L. Briefer, J. Niermeyer, and S. Burian (2013). [Planning for an Uncertain Future: Climate Change Sensitivity Assessment toward Adaptation Planning for Public Water Supply](#). Earth Interactions, Volume 17, Issue 23, 1-26, October, doi: 10.1175/2012EI000501.1.

Bryant, A., T. H. Painter, J. S. Deems, and S. M. Bender (2013). [Impact of dust radiative forcing in snow on accuracy of operational runoff prediction in the Upper Colorado River Basin](#). Geophysical Research Letters, Vol. 40, 3945-3949, doi:10.1002/grl.50773.

Buma, B., E. T. Pugh, and C.A. Wessman (2013). [Effect of the current major insect outbreaks on decadal phenological and LAI trends in Southern Rocky Mountain Forests](#). International Journal of Remote Sensing 34(20): 7429-7274.

Busch, D. E., L. D. Brekke, K. Averyt, A. Jardine, and L. Welling (2013). [Research Strategies for Addressing Uncertainties](#). In Assessment of Climate Change in the Southwest United States: A Report Prepared for the National Climate Assessment, edited by G. Garfin, A. Jardine, R. Merideth, M. Black, and S. LeRoy, 462–482. A report by the Southwest Climate Alliance. Washington, DC: Island Press.

Cayan, D., M. Tyree, K. E. Kunkel, C. Castro, A. Gershunov, J. Barsugli, A. J. Ray, J. Overpeck, M. Anderson, J. Russell, B. Rajagopalan, I. Rangwala, and P. Duffy (2013). [Future Climate: Projected Average](#). In Assessment of Climate Change in the Southwest United States: A Report Prepared for the National Climate Assessment, edited by G. Garfin, A. Jardine, R. Merideth, M. Black, and S. LeRoy, 101–125. A report by the Southwest Climate Alliance. Washington, DC: Island Press.

Cozzetto, K., K. Chief, K. Dittmer, M. Brubaker, R. Gough, K. Souza, F. Ettawageshik, S. Wotkyns, S. Opitz-Stapleton, S. Duren, and P. Chavan (2013). [Climate change impacts on the water resources of American Indians and Alaska Natives in the US](#). Climatic Change, Volume 120, Issue 3, 569-584.

Deems, J.S., T. H. Painter, J. J. Barsugli, J. Belnap, and B. Udall (2013). [Combined impacts of current and future dust deposition and regional warming on Colorado River Basin snow dynamics and hydrology](#). Hydrol. Earth Syst. Sci. 17, 4401-4413.



Dilling, L. and R. Romsdahl (2013). [Promoting Adaptation Success in Natural Resource Management Through Decision Support: Lessons from the Great Plains and Rocky Mountain Regions](#). In: S. Moser and M. Boykoff (eds.), *Successful Adaptation to Climate Change*, Routledge, pp. 180-185.

Gershunov, A., B. Rajagopalan, J. Overpeck, K. Guirguis, D. Cayan, M. Hughes, M. Dettinger, C. Castro, R. E. Schwartz, M. Anderson, A. J. Ray, J. Barsugli, T. Cavazos, and M. Alexander (2013). [Future Climate: Projected Extremes](#). In *Assessment of Climate Change in the Southwest United States: A Report Prepared for the National Climate Assessment*, edited by G. Garfin, A. Jardine, R. Merideth, M. Black, and S. LeRoy, 126–147. A report by the Southwest Climate Alliance. Washington, DC: Island Press.

Grafton, R.Q., J. Pittock, R. Davis, J. Williams, G. Fu, M. Warburton, B. Udall, R. McKenzie, X. Yu, N. Che, D. Connell, Q. Jiang, T. Kompas, A. Lynch, R. Norris, H. Possingham, and J. Quiggin (2013). [Global insights into water resources, climate change and governance](#). *Nature Climate Change* 3, 315–321, doi:10.1038/nclimate1746.

Gordon, E., Pugh, E., and B. Livneh (2014). [Bark Beetles: Cause for Concern in Snowy Western Watersheds?](#) *Utility Intelligence & Infrastructure*, March.

Hoerling, M. P., M. Dettinger, K. Wolter, J. Lukas, J. Eischeid, R. Nemani, B. Liebmann, and K. E. Kunkel (2013). [Present Weather and Climate: Evolving Conditions](#). In *Assessment of Climate Change in the Southwest United States: A Report Prepared for the National Climate Assessment*, edited by G. Garfin, A. Jardine, R. Merideth, M. Black, and S. LeRoy, 74–100. A report by the Southwest Climate Alliance. Washington, DC: Island Press.

Kenney, D. S. (2014). [Understanding utility disincentives to water conservation as a means of adapting to climate change pressures](#). *Journal of American Water Works Association*, Vol. 106, No. 1, January.

Kunkel, K.E., T. R. Karl, H. Brooks, J. Kossin, J. H. Lawrimore, D. Arndt, L. Bosart, D. Changnon, S. L. Cutter, N. Doesken, K. Emanuel, P. Y. Groisman, R. W. Katz, T. Knutson, J. O'Brien, C. J., Paciorek, T. C. Peterson, K. Redmond, D. Robinson, J. Trapp, R. Vose, S. Weaver, M. Wehner, K. Wolter, and D. Wuebbles (2013). [Monitoring and Understanding Trends in Extreme Storms: State of Knowledge](#), *Bull. Amer. Meteor. Soc.*, 94, 499–514. doi: <http://dx.doi.org/10.1175/BAMS-D-11-00262.1>.

Lahsen, M., Bustamante, M. M. C., Swap, R., McNie, E., Ometto, J. P., Schor, T., Tiessen, H., Andelman, S., and H. J. Annegarn (2013). [The contributions of regional knowledge networks researching environmental changes in Latin America and Africa: A synthesis of what they can do and why then can be policy relevant](#). *Ecology and Society*, Vol.18, No. 3, 14.

Liverman, D., S. C. Moser, P. S. Weiland, L. Dilling, M. T. Boykoff, H. E. Brown, E. S. Gordon, C. Greene, E. Holthaus, D. A. Niemeier, S. Pincetl, W. J. Steenburgh, and V. C. Tidwell (2013). [Climate Choices for a Sustainable Southwest](#). In *Assessment of Climate Change in the Southwest United States: A Report Prepared for the National Climate Assessment*, edited by G. Garfin, A. Jardine, R. Merideth, M. Black, and S. LeRoy, 405–435. A report by the Southwest Climate Alliance. Washington, DC: Island Press.

Lukas, J., (2013). September 2013 Front Range Flooding Event: Weather, Hydrologic Impacts, Context of a Changing Climate, Implications. *Colorado Water*, 30:6.



Lukas, J., K. Wolter, K. Mahoney, J. Barsugli, N. Doesken, W. Ryan, I. Rangwala, B. Livneh, E. Gordon, M. Hoerling and G. Kiladis. (2013). Severe flooding on the Colorado Front Range, September 2013: A preliminary assessment. 4 pp.

McNie, E. C. (2013). [Delivering climate services: Organizational strategies and approaches for producing useful climate-science information](#). Weather, Climate and Society. Vol. 5, 14-26.

Meldrum, J. R., K. B. Averyt, J. E. Macknick, R. L. Newmark, J. Rogers, N. Madden, and J. I. Fisher (2013). [Sensitivities of Recent Electricity Generation Water Use Findings to Data Updates and Variability](#). ASME Proceedings, Paper No. POWER2013-98227, pp. V002T10A004; 8 pages doi:10.1115/POWER2013-98227.

Meldrum, J., S. Nettles-Anderson, G. Heath, and J. Macknick (2013). [Life cycle water use for electricity generation: a review and harmonization of literature estimates](#). Environmental Research Letters 8.

Naud, C., Y. Chen, I. Rangwala and J. A. Miller (2013). [Sensitivity of downward longwave surface radiation to moisture and cloud changes in a high elevation region](#). Journal of Geophysical Research 118, 10,072–10,081, doi:10.1002/jgrd.50644.

Overpeck, J., G. Garfin, A. Jardine, D. E. Busch, D. Cayan, M. Dettinger, E. Fleishman, A. Gershunov, G. MacDonald, K. T. Redmond, W. R. 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, edited by G. Garfin, A. Jardine, R. Merideth, M. Black, and S. LeRoy, 1–20. A report by the Southwest Climate Alliance. Washington, DC: Island Press.

Peterson, T. C., R. R. Heim, Jr., R. Hirsch, D. P. Kaiser, H. Brooks, N. S. Diffenbaugh, R. M. Dole, J. P. Giovannetone, K. Guirguis, T. R. Karl, R.W. Katz, K. Kunkel, D. Lettenmaier, G. J. McCabe, C. J. Paciorek, K. R. Ryberg, S. Schubert, V. B. S. Silva, B. C. Stewart, A. V. Vecchia, G. Villarini, R. S. Vose, J. Walsh, M. Wehner, D. Wolock, K. Wolter, C. A. Woodhouse, and D. Wuebbles (2013). [Monitoring and Understanding Changes in Heat Waves, Cold Waves, Floods and Droughts in the United States: State of Knowledge](#), Bulletin of the American Meteorological Society, doi:<http://dx.doi.org/10.1175/BAMS-D-12-00066.1>.

Rangwala, I., E. Sinsky, and J. R. Miller (2013). [Amplified warming projections for high altitude regions of the northern hemisphere mid-latitudes from CMIP5 models](#). Environmental Research Letters, Volume 8, doi:10.1088/1748-9326/8/2/024040.

Rhoades, C. C., J. H. McCutchan, Jr., L. A. Cooper, D. Clow, T. M. Detmer, J. S. Briggs, J. D. Stednick, T. T. Veblen, R. M. Ertz, G. E. Likens, and W. M. Lewis, Jr. (2013). [Biogeochemistry of beetle-killed forests: Explaining a weak nitrate response](#). Proceedings of the National Academy of Sciences, 10.1073/pnas.1221029110.

Steenburgh, W. J., K. T. Redmond, K. E. Kunkel, N. Doesken, R. R. Gillies, J. D. Horel, M. P. Hoerling, and T. H. Painter (2013). [Present Weather and Climate: Average Conditions](#). In Assessment of Climate Change in the Southwest United States: A Report Prepared for the National Climate Assessment, edited by G. Garfin, A. Jardine, R. Merideth, M. Black, and S. LeRoy, 56–73. A report by the Southwest Climate Alliance. Washington, DC: Island Press.



Theobald, D. M., W. R. Travis, M. A. Drummond, and E. S. Gordon (2013). [The Changing Southwest](#). In Assessment of Climate Change in the Southwest United States: A Report Prepared for the National Climate Assessment, edited by G. Garfin, A. Jardine, R. Merideth, M. Black, and S. LeRoy, 37–55. A report by the Southwest Climate Alliance. Washington, DC: Island Press.

Tidwell, V. C., L. Dale, G. Franco, K. Averyt, M. Wei, D. M. Kammen, and J. H. Nelson (2013). [Energy: Supply, Demand, and Impacts](#). In Assessment of Climate Change in the Southwest United States: A Report Prepared for the National Climate Assessment, edited by G. Garfin, A. Jardine, R. Merideth, M. Black, and S. LeRoy, 240–266. A report by the Southwest Climate Alliance. Washington, DC: Island Press.

Travis, W. R. (2013). [Design of a severe climate change early warning system](#). Weather and Climate Extremes, doi: 10.1016/j.wace.2013.10.006, October 30.

Travis, W. R., and M. T. Huisenga (2013). [The effect of rate of change, variability, and extreme events on the pace of adaptation to a changing climate](#). Climatic Change, September.

Udall, B. (2013). [Water: Impacts, Risks, and Adaptation](#). In Assessment of Climate Change in the Southwest United States: A Report Prepared for the National Climate Assessment, edited by G. Garfin, A. Jardine, R. Merideth, M. Black, and S. LeRoy, 197–217. A report by the Southwest Climate Alliance. Washington, DC: Island Press.

Vano, J. A., B. Udall, D. R. Cayan, J. T. Overpeck, L. D. Brekke, T. Das, H. C. Hartmann, H. G. Hidalgo, M. Hoerling, G. J. McCabe, K. Morino, R. S. Webb, K. Werner, and D. P. Lettenmaier (2013). [Understanding Uncertainties in Future Colorado River Streamflow](#). Bulletin of the American Meteorological Society, doi: [10.1175/BAMS-D-12-00228.1](#).

Werner, K., K. Averyt, and G. Owen (2013). [River Forecast Application For Water Management: Oil and Water?](#) Weather, Climate, and Society, Vol. 5, No. 3, pp. 244-253, doi:<http://dx.doi.org/10.1175/WCAS-D-12-00044.1>.

Yates, D., K. Averyt, F. Flores-Lopez, J. Meldrum, S. Sattler, J. Sieber, and C. Young (2013). [A water resources model to explore the implications of energy alternatives in the southwestern US](#). Environmental Research Letters, Vol. 8, No. 4, doi:10.1088/1748-9326/8/4/045004.

Yates, D., J. Meldrum, and K. Averyt (2013). [The influence of future electricity mix alternatives on southwestern US water resources](#). Environmental Research Letters, Vol. 8, No. 4, doi:10.1088/1748-9326/8/4/045005.



APPENDIX B: WWA Appearances in Media

May 13, 2014

"National Climate Assessment"

KGNU Radio - Boulder

Kristen Averyt

May 8, 2014

"How climate change is affecting Utah"

Salt Lake Tribune

Tim Bardsley

May 6, 2014

"Boulder scientists play key role in documenting climate change in U.S."

Daily Camera

Kristen Averyt

May 5, 2014

"New Report Aims to Help Navajo Nation Cope With Climate Change"

Indian Country

Karen Cozzetto

May 1, 2014

"Grass: American Obsession, Environmental Disaster"

Huffington Post

Kristen Averyt

April 27, 2014

"Dust on snow presents problems in runoff"

Daily Camera

April 10, 2014

"Sprawling Navajo Nation confronts climate change and 20-year drought"

ClimateWire

April 10, 2014

"New report summarizes climate considerations on Navajo Nation lands"

Phys.org

Karen Cozzetto



March 1, 2014

"Young preservationists get firsthand look at flood aftermath"

Daily Camera

Klaus Wolter

February 18, 2014

"Despite Fall Floods, Drought Persists in Southeastern Colorado"

NOAA's Climate.gov

Western Water Assessment Study

February 6, 2014

"Lasers Help Scientists Get a Detailed Picture of the West's Snowpack"

Aspen Public Radio

Jeffrey Deems

February 5, 2014

"Scientists get a grip on snowpack"

Aspen Times

Jeffrey Deems

January 29, 2014

"Uncertainty a Big Hurdle in Colorado Climate Planning"

Climate Central

Eric Gordon

January 29, 2014

"Connecting the Drops: Water and Power"

KVNF News

James Meldrum

January 24, 2014

"Rising temperatures challenge Salt Lake City's water supply"

YottaFire

Tim Bardsley

January 22, 2014

"WWA researchers discuss study at climate change roundtable"

NOAA's Climate Program Office

WWA Researchers



January 5, 2014

"Colorado River Drought Forces a Painful Reckoning for States"

New York Times

Brad Udall

December 24, 2013

"Rising temperatures challenge Salt Lake City's water supply"

The Almagest

Tim Bardsley

December 15, 2013

"Water Lines: Dust, higher temps may advance spring snowmelt"

Glenwood Springs Post Independent

Western Water Assessment

December 12, 2013

"10 Cities That Could Run Out Of Water"

The Weather Channel

Western Water Assessment

December 5, 2013

"These 11 Cities May Completely Run Out Of Water Sooner Than You Think"

The Huffington Post

Kristen Averyt

December 3, 2013

"New report seeks early warning system of abrupt climate change events"

Daily Camera

Kristen Averyt

December 2, 2013

"As Temperatures Rise, Salt Lake City Faces An Increasingly Dry Future"

The Weather Channel

Tim Bardsley

December 2, 2013

"DWR: forecast is for mostly dry California winter"

Western Farm Press

Klaus Wolter



November 29, 2013

"Warming and extreme dust could advance spring thaw in Colorado basin by 6 weeks"

NOAA's Climate.gov

Jeffrey Deems

November 28, 2013

"Another Dry Winter?"

Mother Lode

Klaus Wolter

November 27, 2013

"Dust threatens Colorado's water supply"

Colorado Public Radio

Jeffrey Deems

November 16, 2013

"Environment: 'Extreme' dust-on-snow events can speed runoff in Colorado River Basin by six weeks"

Summit County Citizens Voice

Jeffrey Deems

November 15, 2013

"Dust, warming portend dry future for Colorado River"

Aspen Business Journal

Jeffrey Deems

November 15, 2013

"Snowpack Dust Creates Problems for Colorado River"

Environmental News Network

Jeffrey Deems

November 14, 2013

"New study: Dust, warming portend dry future for the Colorado River"

University of Colorado News

Jeffrey Deems

November 6, 2013

"Salt Lake City water managers troubleshoot climate change with local data"

High Country News

Tim Bardsley



November 6, 2013

["Oklahoma vs. Texas \(Water, Not Football\)"](#)

National Geographic

Western Water Assessment

November 6, 2013

["The Rundown: Examining the Effects of Rising Temperatures on Local Watersheds\)"](#)

KCPW Radio

Tim Bardley

November 5, 2013

["Utah must prepare for impact of climate change "](#)

Salt Lake Tribune

Tim Bardsley

November 5, 2013

["Episode 6: The Changing Face of Water Management"](#)

Utah Public Radio

Tim Bardsley

November 5, 2013

["Climate change likely to affect streams that quench Salt Lake City's thirst"](#)

Environmental News Network

Tim Bardsley

November 4, 2013

["Rising Temperatures Challenge Salt Lake City's Water Supply"](#)

Red Orbit

Tim Bardsley

November 4, 2013

["Salt Lake City lays plans for dwindling water supply"](#)

E&E

Tim Bardsley

November 2, 2013

["Warmer Temperature May Reduce Water Supply in Salt Lake City"](#)

Headlines & Global News

Tim Bardsley



November 2, 2013

["Boulder climate change experts encouraged by Obama's actions"](#)

Daily Camera

Tim Bardsley and Kristen Averyt

November 2, 2013

["Climate Change Will Significantly Deplete Salt Lake City's Water Supply for Every Degree Fahrenheit Risen"](#)

University Herald

Tim Bardsley

November 2, 2013

["Rising temperatures may threaten Salt Lake City's water supply"](#)

Science Recorder

Tim Bardsley

November 1, 2013

["Rising temps challenge Salt Lake City's water supply"](#)

Boulder i Journal

Tim Bardsley

November 1, 2013

["Salt Lake City water managers prepare for a challenging future"](#)

Salt Lake City Tribune

Tim Bardsley

November 1, 2013

["New study: Rising temperatures challenge Salt Lake City's water supply"](#)

American Geophysical Union Press Release

Tim Bardsley

November 1, 2013

["Salt Lake City Mayor Appointed to White House Task Force on Climate Change"](#)

KUER Radio

Tim Bardsley

November 1, 2013

["New study: Rising temperatures challenge Salt Lake City's water supply"](#)



e! Science News

Tim Bardsley

October 30, 2013

"Two perspectives take on drought, water in West"

Durango Herald

Kristen Averyt and Imtiaz Rangwala

October 28, 2013

"How does the Colorado River drought stack up?"

High Country News

Jeff Lukas

October 21, 2013

"Caterpillar moth aside, when predicting winter weather, most left out in cold"

The Grand Junction Daily Sentinel

Klaus Wolter

October 11, 2013

"Colorado No Stranger To Flooding, Extreme Conditions"

CBS News

Kelly Mahoney

October 9, 2013

"More Water Stress than Meets the Eye"

National Geographic

Kristen Averyt

October 8, 2013

"Flood Forensics: Why Colorado's Floods Were So Destructive"

Utah Public Radio

Klaus Wolter

October 8, 2013

"What Trees Know about Drought"

Utah Public Radio

Western Water Assessment

September 30, 2013

"Warning: Many watersheds in US failing 'stress test'"



CNBC

Kristen Averyt

September 26, 2013

"Report: Colorado flooding was 'unprecedented'"

USA Today

Jeff Lukas

September 26, 2013

"Could the 'biblical' northern Colo. floods have been predicted?"

Climate Wire

Jeff Lukas and Klaus Wolter

September 25, 2013

"Were Colorado floods result of global warming? Probably not"

Christian Science Monitor

Jeff Lukas and Klaus Wolter

September 25, 2013

"Boulder storm summit: Questions linger among experts"

Daily Camera

Jeff Lukas and Klaus Wolter

September 25, 2013

"Almost One in 10 Watersheds 'Stressed,' Challenges Ahead for Utilities, Agriculture"

Bloomberg BNA

Kristen Averyt and James Meldrum

September 24, 2013

"Nearly One In 10 U.S. Watersheds Is 'Stressed'; Demand For Water Outpacing Supply: CIRES Study"

Huffington Post

Kristen Averyt

September 24, 2013

"Extreme weather: How unusual were September's floods?"

Denver iJournal

Jeff Lukas



September 23, 2013

["Climate change to pose new challenges for already-stressed Western watersheds"](#)

Climate Wire

James Meldrum

September 20, 2013

["What Is the Climate Change Context behind the Colorado Floods?"](#)

Scientific American

Joe Barsugli

September 19, 2013

["1 in 10 Watersheds in the Continental US Stressed with Number Likely to Grow"](#)

Nature World News

Kristen Averyt and James Meldrum

September 18, 2013

["Today's worst watershed stresses may become the new normal, study finds"](#)

University of Colorado Boulder Press Release

Also appeared in *Aspen Business Journal* and *Earth Sky*

Kristen Averyt and James Meldrum

September 17, 2013

["WATER LINES: The silver lining — flood ends drought in northern Colorado"](#)

Grand Junction Post Independent

WWA's Climate Dashboard

August 19, 2013

"Are reduced Colorado River releases a sign of things to come?"

Environment & Energy Daily

Balaji Rajagopalan and Jeff Lukas

August 13, 2013

["WATER LINES: Do recent rains mean the end of the drought?"](#)

Glenwood Springs Post Independent

Western Water Assessment

August 13, 2013

["RMBL hosts panel discussion on future of the Gunnison Valley"](#)

Crested Butte News

Imtiaz Rangwala



August 13, 2013

"Climate change talks hot, heavy"

Gunnison Country Times

Imtiaz Rangwala

August 12, 2013

"Meeting Energy Demands with Less Water"

Colorado Matters, Colorado Public Radio

Kristen Averyt

August 6, 2013

"Speakers Discuss Science Policy Challenges in the Water-Energy Nexus"

Eos, Transactions American Geophysical Union

Kristen Averyt

August 5, 2013

"What will happen when the cheap water and power run out in Arizona?"

Phoenix Business Journal

Kristen Averyt

July 28, 2013

"Is it time to panic over lack of water?"

Durango Herald

Jeff Lukas

July 16, 2013

"Power plants that need water might be at risk"

Toledo Blade

Kristen Averyt

July 9, 2013

"Water worries: Climate change in the desert Southwest"

USA Today

Various WWA members

June 26, 2013

"Study: Colorado River vulnerable to 'megadrought'"

The Coloradoan

Brad Udall



April 19, 2013

"Southwestern dust found in snow across Colo. mtns"

The Denver Post

Jeffrey Deems

March 20, 2013

"Expert to talk 'strange bedfellows'"

The Durango Herald

Imtiaz Rangwala

January 30, 2013

"Water Demand for Energy to Double by 2035"

National Geographic Daily News

Kristen Averyt