

# **The Western Water Assessment**

**Annual RISA Report**  
**Reporting Period:**  
**January 2007-December 2007**



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**WWA Mission:** *The mission of the Western Water Assessment is to identify and characterize regional vulnerabilities to climate variability and change, and to develop information, products and processes to assist water-resource decision-makers throughout the Intermountain West.*

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## **I. Areas of Focus**

A list of ongoing projects with a brief description will be supplied as an appendix to this memo. In very general terms, here are our current focus areas:

**Geographic:** Front Range of Colorado and entire Colorado River are our primary focus areas. We have some involvement in Wyoming and New Mexico via paleoclimate activities, and now have one researcher based in Utah.

**Temporal:** Historically, our efforts have been oriented towards paleoclimate and seasonal forecasting because of stakeholder requests. In the past two years, however, most requests have been for climate change related information. We anticipate the demand for climate change information will only grow over time but we will continue to service seasonal and paleoclimate needs.

**Sectoral:** We continue to focus on water from both supply side and demand side perspectives. Although we are peripherally involved in other sectors, e.g., agriculture and tourism, water provides the best returns for engaging the broadest range of stakeholders given limited resources.

**Outreach and Educational Focus:** Over the past two years, we've substantially stepped up these efforts and have held or sponsored approximately 20 workshops, published the Intermountain Climate Summary on a regular basis, provided more than 40 invited talks at various high profile events, and have begun to utilize our website as a regional climate information clearinghouse. We anticipate this directed effort will continue.

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## **II. Primary Stakeholders & Partners**

(See appendix for a list of individual contacts)

### **State and Municipal Agencies and Water Managers**

State agencies include the Colorado Water Conservation Board and Water Availability Task Force; regional organizations include the Northern Colorado Water Conservancy District, and Colorado River Water Conservation District; and municipal entities include the cities of Denver, Aurora, Colorado Springs, and Boulder.

### **Colorado River Basin State and Municipal Agencies and Water Managers**

These include the California Department of Water Resources, Salt River Project in Arizona, Wyoming State Engineer, New Mexico State Engineer, Southern Nevada Water Authority, and Upper Colorado River Commission. The Lower Colorado Bureau of Reclamation is a critical stakeholder.

#### **National Weather Service including the Colorado River Basin Forecast Center**

We consider NWS an important stakeholder and partner. This includes Regional Climate Focal Points, Climate Services Division, Climate Prediction Center, Local WFOs and the Colorado Basin River Forecast Center.

#### **Natural Resource Conservation Service**

The NRCS is an important partner and information source for the Intermountain West Climate Summary. We are in constant communication with the NRCS for updated water and climate information useful in WWA research.

#### **Colorado Judicial System**

Colorado Supreme Court Justice Hobbs is a noteworthy stakeholder.

#### **Other**

The Western Governors' Association is a critical stakeholder. WWA has been providing policy and scientific advice to the recently announced Water Utility Climate Alliance, which is comprised of Seattle, Portland, San Francisco, Metropolitan Water District, San Diego County Water Authority, Las Vegas, Denver, and New York City. WWA is also a member of the newly created American Water Works Association Research Foundation Climate Change Expert Committee.

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### **III. Research Highlights**

#### ***1. Outreach, Education and Directed Climate Products***

##### **Project Title: The Intermountain West Climate Summary**

**PI's:** Andrea Ray, NOAA, Jessica Lowrey, CIRES, Christina Alvord, CIRES, Julie Malmburg, CIRES, Barb Deluisi, CIRES

The Intermountain West Climate Summary (ICS) provides the latest climate information in a simple compact document aimed at managers, planners, and policy makers with water-related interests. By improving awareness and understanding about forecasts as well as climate phenomenon, the climate summary helps WWA facilitate a dialog among potential users, researchers and operational providers of climate information with the ultimate goal of providing enhanced climate services. The ICS is typically released eight times per year and is posted on the WWA website.

[http://wwa.colorado.edu/products/forecasts\\_and\\_outlooks/intermountain\\_west\\_climate\\_summary/](http://wwa.colorado.edu/products/forecasts_and_outlooks/intermountain_west_climate_summary/)

ICS e-mail: [wwasummary@wwa.colorado.edu](mailto:wwasummary@wwa.colorado.edu)

**Project Title: Web Development****PI's:** Chris Goemans, CIRES, Christina Alvord, CIRES, Brad Udall, CIRES*Homepage & General Development:*

Web development is a primary research and outreach tool that can serve as a clearinghouse of information, education resource, facilitate project collaboration, and foster partnership for a wide range of user groups. In the past year, WWA has focused on developing a new website, scheduled to launch in spring of 2008. WWA has been working closely with a consultant to redesign the homepage, subpages, and html programming needs. The new webpage content and presentation is centered on topic headings to appeal to a wide range of user groups and corresponding knowledge base. Topic headings include: "Colorado River", "Front Range", "Western Hydrology", "Water Management and Drought", "Climate Variability and Change", and "Forecasts and Outlooks." In the coming year, WWA will launch the new website and continue to add content. Researchers Chris Goemans, CIRES, Christina Alvord, CIRES, Brad Udall, CIRES.

*Colorado River Resources website: (Climate, Management, Law and Policy):* Based on a google web analysis, the Colorado River resource webpages constitute for nearly half of WWA web visitors, and thus is an important component to the website. The goal is to enhance and update existing site on matters of interest to Colorado River water managers. In addition, we will add discussion of useful existing climate products and new climate product needs by water managers. Researchers Roger Pulwarty, NOAA, Doug Kenney, NRLC, Andrea Ray, NOAA, Brad Udall, CIRES, Jessica Lowrey, CIRES, Christina Alvord, CIRES

URL: [http://wwa.colorado.edu/resources/colorado\\_river/](http://wwa.colorado.edu/resources/colorado_river/)

*Colorado River Streamflow - A Paleo Perspective website.*

This site, which went online in spring 2007, provides context for and information about long-term variations in streamflow for the Colorado River basin, including the 2006 Woodhouse et al. and Meko et al. 2007 tree-ring reconstructions of flow at the Lees Ferry gage. Researchers Connie Woodhouse, University of Arizona, Jeff Lukas, INSTAAR, and David Meko, University of Arizona-CLIMAS.

URL <http://wwa.colorado.edu/resources/paleo/lees/>

*TreeFlow: Tree-Ring Streamflow Reconstructions for the West website.*

In 2007, the existing web resource for WWA paleoclimate research was revised and expanded to serve as a clearinghouse for information about the development and application of paleohydrologic data (streamflow reconstructions) to water management in the West. The content includes background information, descriptions of specific applications of the reconstructions, pages for each technical workshop (see below), access to reconstruction data, and the Colorado River Paleo Perspective pages (described above). In 2008, this web resource will be expanded further to more explicitly cover regional tree-ring projects, applications, and data across the West, in collaboration with researchers from CLIMAS, CIG, and CAP.

Researchers Connie Woodhouse, University of AZ, Jeff Lukas, INSTAAR  
URL: <http://wwa.colorado.edu/resources/paleo>

### *Climate Change Webpages*

In the last year, it became evident that a climate change web section parallels WWA research areas and user group needs. Currently, a climate change web section is currently in development, with individual sections dedicated to trends and projections, water and climate, impacts and vulnerabilities, adaptation and mitigation, climate workshops and symposiums, WWA climate research and products, and climate vocabulary, concepts, and resources. The climate change web section will be debuted with the new website, spring 2008. Researchers Christina Alvord, CIRES, Chris Goemans, CSU

## ***2. Municipal Water Management along the Front Range, CO***

### **Water Rights and Climate Change Project**

**PI's: Douglas Kenney, NRLC, Bobbie Klein, CSTPR, Christina Alvord, CIRES, Chris Goemans, CSU**

WWA launched a project in June 2007 that addresses the impact of earlier timing of spring snowmelt on water rights in the West. In many basins, snowmelt is coming earlier than in historic times, prompting holders of prior appropriation water rights to demand water at an earlier calendar date than in the past. This is obviously problematic for those rights defined in terms of specific calendar dates (associated with historic patterns of use). In addition, for senior rights defined more generally (e.g., such as an "irrigation season" right), the net effect may be to increase the diversion season and, thus, the size of the right with the result that junior rights may be harmed. This project will examine the extent to which this problem exists in the West by analyzing temporal language evident in state statutes, rules, permits, and applications in the eleven western states in conjunction with interviews with regional water managers, attorneys, and engineers. In addition, case studies will be completed for Colorado, Idaho, Wyoming, and Utah. Project completion timeframe is July 2007-August 2007 with potential for Phase II of study. Researchers Kenney, NRLC, Klein, CSTPR, Goemans, CSU, Alvord, CIRES.  
URL: [http://wwa.colorado.edu/current\\_projects/water\\_rights\\_climate\\_change.html](http://wwa.colorado.edu/current_projects/water_rights_climate_change.html)

### **Front Range Climate Change Future Hydrology Study**

**PI's: Brad Udall, CIRES, Jessica Lowrey, CIRES**

Several Front Range water providers are working together to fund a study of the potential impacts of climate change on water resources in Colorado. They will use a variety of downscaled GCM projections in two different hydrology models to identify streamflow changes in 2040 and 2070. WWA is serving on an internal advisory committee to provide guidance on choosing GCMs and emissions scenarios along with climate variables and data sets to put into the hydrology models. In addition, WWA organized an education workshop for the water providers that covered the fundamentals and differences of GCMs, emissions scenarios, downscaling techniques, and hydrology modeling. Once future streamflows are obtained, WWA will provide guidance on planning for and communication of results. Researchers Brad Udall, CIRES, Jessica Lowrey, CIRES, Joe Barsugli, NOAA, ESRL, Chris Anderson, NOAA.

URL: [http://wwa.colorado.edu/resources/climate\\_change\\_modeling.html](http://wwa.colorado.edu/resources/climate_change_modeling.html)

**Project Title: Assessment of user needs for climate information and forecasts**

**PI's:** Jessica Lowrey, CIRES and Andrea Ray, NOAA

We have finished collecting information and are writing up our research on the uses and needs of Colorado municipal water managers for climate information and forecasts. The results, which were presented at the Climate Prediction Assessment Workshop in March 2008, show that water managers rely heavily on annual snowpack and streamflow conditions and the past hydrologic record in their operations and planning models. However, these water managers do not use climate forecasts quantitatively. In contrast, streamflow forecasts are used quantitatively because they are specific to river basins and gauge locations, and the format is appropriate for input to operational models. Water managers are more likely to use climate information and forecasts if their water annual water availability is more sensitive to climate variability, if they have a high institutional capacity to learn about and use new information, and if they understand the climate system and its effects on water availability. In the past few years, through this project and other WWA education and communication efforts with water managers, we have seen a change in understanding and interest in climate information: water managers are increasingly coming to the WWA for information about climate, and guidance about how to use it. As a result of these interactions, water managers are taking steps to use more climate information and to incorporate risk of climate variability in annual operations and long-term planning.

Deliverables include the presentation at the 6th annual Climate Prediction Application Science Workshop in March 2008, an article in preparation for *Water Resources Research*, a report for WWA with detailed results about uses and need for climate information from each water provider, a white paper for CPC about information presentation, and an article in the ICS about uses of climate information and forecasts.

**Project Title: Front Range Water Demand**

**PI's:** Douglas Kenney, NRLC, Bobbie Klein, CIRES, Chris Goemans, CIRES, and Jessica Lowrey, CIRES

WWA continues its focus on residential water demand as an important adaptation mechanism for municipal water systems coping with climate variability and change. Our study of several water demand management tools utilized by Aurora Water (the municipal water utility serving Aurora, CO) ended this past year. This research involved compiling a database of household water-use statistics, and conducting an analysis of that data to better evaluate the efficacy of various demand management tools (e.g., pricing policies, outdoor watering restrictions, technology rebate programs) employed by the City of Aurora over the past 5 years, a turbulent period featuring severe drought conditions and a variety of management interventions. A Phase 2 of the study is under consideration. Researchers Douglas Kenney, NRLC, Bobbie Klein, CIRES, Chris Goemans, CSU, and Jessica Lowrey, CIRES

URL: [http://wwa.colorado.edu/resources/water\\_demand\\_and\\_conservation/aurora.html](http://wwa.colorado.edu/resources/water_demand_and_conservation/aurora.html)

### ***3. Colorado River Basin Research***

#### **Project Title: Reconciling Future Colorado River Flows**

**PIs: Nick Graham (HRC), Dan Cayan (CAP), Dennis Lettenmaier, Andy Wood (CIG), Robert Webb, Brad Udall, (WWA) Martin Hoerling (NOAA-WWA), Jonathan Overpeck, Holly Hartman (CLIMAS)**

Within the Upper Colorado River Basin, projected reductions in naturalized streamflow by the mid 21st century tied to climate change range significantly based on findings from recent scientific literature. Projected reductions in streamflow range from ~45% by Hoerling and Eischeid (2007), 10 to 25% by Milly et al (2005), ~18% by Christensen et al. (2004), and ~6% by Christensen and Lettenmaier (2007). In addition, the recent Seager et al (2007) analysis of future P-E (a proxy for runoff) suggests an "imminent transition to a more arid climate in southwestern North America". This wide range of future Colorado River streamflow projections makes it difficult for decision makers and water managers to prepare and plan for potential future reductions in streamflow resulting from climate change. The goal of this project is to reconcile future Colorado River streamflow projections by evaluating the various methodologies and models being used in projections and to understand why different modeling approaches produce varying flow reduction amounts. The second component of this project entails identifying a common subset of appropriate climate scenarios and models in development of future projections of streamflow; and using these scenarios and models to generate a consistent suite of Colorado River streamflow projections by the mid to late 21st century. Results will directly apply to the needs of water planners across the western U.S., and similar mid-latitude continental regions where water resources are heavily dependent on snowmelt runoff from mountainous headwater areas. Project URL: [http://wwa.colorado.edu/resources/colorado\\_river/reconciling\\_future\\_streamflow\\_projects.html](http://wwa.colorado.edu/resources/colorado_river/reconciling_future_streamflow_projects.html).

#### **Project Title: Paleoclimate Research & Workshops**

**PIs: Jeff Lukas, INSTAAR; Connie Woodhouse, University of Arizona**

This project encompasses several separate but related projects which have the common goal of making paleoclimate records developed from tree rings more accessible, credible, and useful to water managers and stakeholders in the region. Most have a direct nexus with our Colorado River research. URL: <http://wwa.colorado.edu/resources/paleo/>.

#### ***Non-parametric streamflow reconstructions***

Non-parametric techniques have been successfully used in other areas of hydrologic modeling, but have not yet been applied to tree-ring reconstructions. This project, funded by WWA and the US Bureau of Reclamation, aims to develop and prove a methodology for using a non-parametric *k*-nearest-neighbor technique to generate a streamflow reconstruction, for the Colorado River at Lees Ferry, which is driven more directly by the tree-ring data. A preliminary reconstruction for Lees Ferry has been successfully generated using the new non-parametric methodology, and was presented to the Colorado River Hydrology Working Group (US Bureau of Reclamation) in January 2008. Work in the coming year will include testing techniques for reconstructing extreme high and low



flows. Researchers: Subhrendu Gangopadhyay, AMEC; Ben Harding, AMEC, Lukas, Woodhouse, Balaji Rajagopalan, CIRES; Robert Webb, NOAA.

#### *New reconstructions for the Upper Colorado River Basin*

Building on the 462-year reconstruction of annual streamflow for the Colorado River at Lees Ferry developed from living trees (Woodhouse et al. 2006), a new reconstruction for Lees Ferry was developed using remnant material (dead trees, logs, stumps) to extend the record of reconstructed flows back to 762 AD (1244 years), in collaboration with University of Arizona researchers (Meko et al. 2007). This reconstruction was the basis for some of the analyses the US Bureau of Reclamation performed for the Colorado River Shortage EIS to assess shortage criteria and coordinated reservoir operations in the Colorado River (Appendix N). Researchers: David Meko (University of Arizona/CLIMAS), Woodhouse, Lukas.

#### *Evaluation of the use of Tree-Ring Data in Water Resource Management*

The evaluation of the use of dendrochronological reconstructions and information by water resource managers and consultants is a two-phase project begun in the fall of 2007. The goal of the project is to assess how partner organizations have utilized the tree-ring data they were provided, how these data have affected operations and decision-making within each organization, any challenges/opportunities that have been encountered in this process, as well as any future needs these organizations may have regarding the use or acquisition of paleoclimatic data for water resource management. The first part of this evaluation project was a set of in-person interviews with the partners at Denver Water, the City of Boulder, Northern Colorado Water Conservation District (NCWCD), and Hydrosphere and Stratus Consulting firms, conducted by University of Arizona graduate student, Jennifer Rice in January 2008. The second part is an online survey sent to approximately 80 participants of the technical workshops, sent out in February 2008. Synthesis in the form of an internal report and peer-reviewed publication will be completed in 2008. Researchers: Woodhouse, Lukas, Jennifer Rice (University of Arizona).

#### *Support of tree-ring analyses for Colorado River Shortage EIS*

In 2006 and 2007, the US Bureau of Reclamation prepared an Environmental Impact Statement (EIS) regarding lower basin shortage criteria and coordinated reservoir operations on the Colorado River. Woodhouse and Lukas provided data and technical support to James Prairie (USBR) and Jose Salas and Zeyad Tarawneh (CSU), who were performing separate hydrologic analyses for the EIS using the tree-ring reconstructions of streamflow developed by Woodhouse and others (Woodhouse et al. 2006, Meko et al. 2007). Woodhouse and Lukas also participated in the quarterly meetings of the Colorado River Hydrology Working Group, a group of USBR managers and engineers and university researchers working on analyses for the EIS, and were recognized by USBR for their efforts in support of the EIS. Researchers: Woodhouse, Lukas.

#### *Development and Comparison of Long-Term Planning Hydrologies using Alternate Climate Information Sets*

This project, funded by US Bureau of Reclamation with WWA support, began in late 2007 and will last one year. Long-term water resources planning evaluations typically involve multi-decade simulations of operations forced by a hydrologic time series consistent with the instrumental record. The implied assumption is that hydrology of the instrumental record adequately portrays the hydrologic variability envelope that could occur during the evaluation's look-ahead horizon. The US Bureau Reclamation has begun to test this paradigm and experiment with modified hydrologic assumptions that account for both instrument record and paleoclimate or projected climate information. However, joint accounting for paleoclimate and projected climate information has yet to be demonstrated within Reclamation. Questions to be addressed include: 1) How do planning hydrologies vary when developed using alternative climate information sets (e.g., blends of instrument record, paleoclimate data, climate projections)? 2) How can paleoclimate and projected climate data be jointly accounted for within long-term planning hydrologies? Researchers: Levi Brekke, USBR; Rajagopalan, Woodhouse, Lukas.

#### *Paleoclimate Workshops*

Woodhouse and Lukas held four technical workshops in Colorado, Wyoming, and New Mexico during 2007, providing over 75 water managers and other data users with information about how the tree-ring data and reconstructions of streamflow are generated, the characteristics of these data, and how water entities are successfully incorporating the data into modeling and planning. See “Workshops, Meetings, & Presentations” for more information. Workshops will be held in several locations in 2008. Researchers: Woodhouse, Lukas.

#### **Project Title: Lower Colorado Environmental Impact Statement Climate Change Appendix**

**PI's:** Brad Udall, CIRES, Terry Fulp, BOR, Levi Brekke, BOR, David Yates, NCAR, Tom Piechota, UNR, Ben Harding, Hydrosphere Consultants, Klaus Wolter, CIRES

In response to the five-year 1999-2004 drought, Reclamation began an Environmental Impact Statement (EIS) in 2005 to determine how to operate Lakes Mead and Powell in a coordinated fashion, and to establish objective criteria for declaring and implementing shortages on the Colorado River. The “*Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lakes Powell and Mead*” EIS was released in December, 2007. The Western Water Assessment, along with several collaborators including NCAR, USBR, CLIMAS, and NOAA formed a “Climate Technical Working Group” to provide an appendix in the EIS containing a broad overview of past climate change studies, the current state of the climate change science for regional planning, and a set of potential future work items to help narrow the uncertainty on hydrologic projections. The Climate Technical Working Group Report (Appendix) U is available at:

<http://www.usbr.gov/lc/region/programs/strategies/FEIS/AppU.pdf>.

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## **IV. List of Stakeholder workshops, newsletters, list serves, media briefings**

### **Newsletters**

**Intermountain West Climate Summary**: see previous description.

### **Workshops, Meetings & Presentations 2007**

(Organized alphabetically by meeting/conference name. This list is not complete but it does provide a broad overview of our extensive activities in this field. )

#### **American Geophysical Union (AGU) Annual Conference**

- Painter, T. H., M. P. Flanner, J. C. Neff, C. Zender, and N. Mahowald presented *Climate response in the western United States to dust-shortened snow cover duration since late 1800s soil disturbance*, San Francisco, CA, December 11, 2007.
- Kenney presented *Climate and Management of the Colorado River: What Does the SSD Study Tell Us About Scenario Analysis?* San Francisco, CA; December 11, 2007.

#### **American Geophysical Union Joint Assembly**

Woodhouse presented *Drought and Patterns of Circulation Inferred from Tree-Ring Data in Western North America*. This presentation was part of special session at AGU called “Long-Term Drought in the Americas and Linkages to Pacific Ocean Variability”. Acapulco, Mexico, May 22-25, 2007.

#### **American Meteorological Society (AMS) Annual Meeting**

Wolter gave invited review talk on *International high impact weather and climate events of 2006*, hosted a special session on the new Multivariate ENSO Index project, and gave a talk on experimental seasonal forecast guidance, *Statistical Climate Prediction for the Southwestern U.S.: A Seven-Year Assessment*. San Antonio, Texas, January 2007.

#### **AMS Second Symposium on Policy and Socio-economic Research.**

Ray and Kenney presented *Critical challenges in incorporating climate into management of the Colorado River*, San Francisco, CA, January 18, 2007.

#### **AMS Symposium on Fire and Forecast Meteorology**

Wolter presented *Eight Years of Seasonal Climate Forecasting for the Wildfire Management Community*, Bar Harbor ME, October 2007.

#### **American Water Resources Association (AWRA) Meeting**

Goemans presented *Residential Demand Management as a Drought Coping Tool*, AWRA, Denver, CO, Nov. 13, 2007

### **Climate Change Adaptation Workshop for New Mexico Natural Resource Managers**

Ray was invited to represent WWA at this invite-only meeting dedicated to regional adaptation strategies for adjusting a variable climate, Albuquerque, NM, Oct. 22, 2007.

### **Climate Prediction Assessment Workshop (CPAS)**

Ray presented *Lessons learned from the 2000s Western drought: Evolving linkages between research and services*. This talk described lessons learned by WWA in the delivery of experimental climate services during the multi-year drought period, with experiences drawn from user studies and other activities targeting a variety of stakeholders. Based on these experimental climate services, linkages between science and services have evolved within WWA and provide useful lessons for climate services design and on the role of climate information in adaptive management in general. Seattle, WA, 20-23, 2007.

### **Climate and Tourism Workshop, UCAR, January 22-23, 2007**

This workshop co-sponsored by WWA and the Center for Sustainable Tourism, Leeds School of Business, University of Colorado, focused on the development of a strategic research agenda to assess the economic, socio-cultural and environmental implications of climate extremes, variability and change for sustainable tourism for Colorado Plateau states of Colorado, Arizona, New Mexico, and Utah. A summary article was generated and scheduled for May 2008 publication in Bulletin of Meteorological Society. WWA planning team: Christina Alvord, CIRES, Brad Udall, CIRES, Roger Pulwarty, NOAA. URL: <http://wwa.colorado.edu/outreach/climatetourworkshop.html>

### **Collaboration and the Colorado River Conference; Boyd School of Law, University of Nevada**

Kenney presented *Collaboration and Restoration of the Colorado River Delta*, Las Vegas; NV, October 12, 2007.

### **CO River Water Users Association Annual Conference**

Udall presented *Climate Change and the Colorado River: Recent Observations and Future Projections*. This annual conference brings together Colorado River water users representing a variety of agencies to promote collaboration and partnership in managing water resources on the Colorado mainstem and its tributaries. Las Vegas, NV, December 12-14, 2007.

### **Colorado River Water Conservancy District, State of the River Meeting**

Alvord and Ray presented *IPCC 4th Assessment Report: Physical Basis of Climate Change and Adaptation, Impacts and Vulnerability*, including climate trends and projections, human and natural causes, resulting impacts on regional water resources, and potential adaptation measures. These talks reached over 400 people in audiences with water user entities including irrigators, municipal users, industry, federal, state, county and local agencies and private entities.”

- 1) Grand Junction, CO, April 2007, (Ray)
- 2) Grand Junction, CO, May 2007, (Alvord)
- 3) Frisco, CO, May 2007 (Ray)

### **Colorado Water Congress: 2007 Summer Convention: Climate Change and Water Management: Planning for the Future**

This annual conference addressed climate trends and projections, attributions of climate variability and change, impacts to water resources, and potential water management entities can adapt. WWA personal in attendance: Brad Udall, CIRES. Steamboat Springs, Colorado, August 22-24, 2007.

### **Colorado Water Congress Annual Meeting**

Udall presented *Climate Change and Colorado's Water*. The presentation addressed IPCC AR4 findings, an introduction to hydrology and the interplay with climate conditions, an overview of current temperature, precipitation, and SWE research in the West, and an overview of previous studies dedicated to climate impacts on Colorado River flows. Denver, CO, Jan 25, 2007.

**Colorado Water Conservation Board (CWCB) Water Availability Task Force (WATF) Collaboration and Assistance:** Provide technical support for Governor's drought task force as needed. Researchers Klaus Wolter, CIRES, Jessica Lowrey, CIRES, Andrea Ray. NOAA, Colorado DOW Office, Denver, CO, monthly meetings.

URL: <http://www.cwcb.state.co.us/Conservation/Drought/waterAvailability.htm>  
[http://wwa.colorado.edu/themes/current\\_research/watf\\_meetings.html](http://wwa.colorado.edu/themes/current_research/watf_meetings.html)

### **Continuing Legal Education, Law of the Colorado River**

Udall presented *Climate Change and the Colorado River* in Las Vegas on May 10, 2007.

### **EPA Climate Change Workshop**

Woodhouse presented *Climate Change: A Perspective from Paleoclimatology and Observations*. The goal of this work, Climate Change Effects on Biological Indicators (co-sponsored by the GCRP) was to assist state and tribal bio criteria managers to begin the process of determining the effects of climate change and creating opportunities for adaptation of management approaches. Baltimore, MD, March 27-29, 2007.

### **52<sup>nd</sup> New Mexico Water Conference: Beyond the Year of Water: Living with our Water Limitations**

Pulwarty presented *Climate Research and Applications Needs in Support of Climate Services*. This workshop brings together a wide range of water users including municipal water managers, tribal councils, business owners, and farmers, to address state and basin water needs. Santa Fe, NM, November 29-30, 2007.

### **Global Earth Observing System of Systems (GEOSS) Workshop: Regional Decisions for Climate Change**

Ray presented *Integrating climate science w/ regional planning and policy*, covering recent findings from an ongoing study that is examining how water managers use climate information. This workshop addressed how GEOSS will support citizens and public officials in making decisions based upon predictions of regional climate change. Boulder, CO, September 21, 2007.

<http://www.ucgis.org/summer2007/Schedule.htm#Slideshow>

### **International Union for Geodesy and Geophysics**

Painter, T. H., J. Dozier, P. Slaughter, and J. Frew presented *MODIS Fractional Snow Cover Products for Hydrologic Science with Space-Time Consistency*, Perugia, Italy.

### **National Congress of American Indians Annual Meeting**

Kenney presented *Climate Change & Water Resources: Trends, Projections, and Implications for the Western US*, focusing on impacts to Tribal resources, and potential mitigation and adaptation resources and solutions, Denver, Colorado, November 13, 2007.

[http://wwa.colorado.edu/about/homepages/kenney/kenney\\_ncai\\_2007.pdf](http://wwa.colorado.edu/about/homepages/kenney/kenney_ncai_2007.pdf)

### **NIDIS Executive Council Meeting, NOAA, October 30-31, 2007**

This meeting brought together members of the NIDIS Executive Council to discuss goals and milestones for 2008 including the launching of the regional test pilots in the Colorado River basin and Southeastern US, organization and implementation of a federal climate office, and organization of three knowledge based workshops over the next year. WWA personal attendees include Brad Udall, CIRES, Christina Alvord, CIRES, Roger Pulwarty, NOAA. NOAA, Boulder, Colorado. (Special note: WWA, through the services of Christina Alvord, has provided NIDIS with substantial logistical help in setting up this and other conferences.)

### **Liquid Assets: Using Water in the Arid Southwest**

Woodhouse presented *Variable Precipitation and Drought in the Southwest through Time*. This was a public symposium on the challenges of how to obtain, distribute, use, and conserve water at a time of rapid growth and development in the Southwest, addressed from cultural and historical perspectives. Santa Fe, NM, November 3, 2007.

### **Mountain Hydroclimate & Water Resources Workshop, NASA, NOAA**

Ray presented *Challenges for managing water resources in mountainous regions* focused the 2007 policy environment for water in the West, including the shortage sharing agreement for the Colorado River, and the potential management implications of long-term drought and climate change. It described some needs for monitoring, understanding, and predictions of mountain hydroclimate from a water management perspective, and in terms of what understanding and predictive capabilities are needed to manage ecological and water resources in the mountains. Boulder, CO, October 17-19.

### **National Seasonal Assessment Workshop (NSAW) for wildfire potential in the Western U.S. and Alaska**

Wolter presented seasonal climate outlooks for the interior southwestern U.S., composites for all of North America, due to Alaskan, Canadian, and Mexican interests, review of 2006 forecasts that showed skill in that forecast cycle, Boulder, CO, April 2007.

**Paleohydrology and its use in water management in the southwest US.** This meeting was focused on applying paleoenvironmental data to water management for hydropower in. This was a meeting of managers from Manitoba and paleoscientists from across Canada. WWA personnel in attendance: Jeff Lukas, INSTARR, Manitoba; Winnipeg, MB, Canada, September 20, 2007.

### **Rio Grande County Museum Monthly Talk Series**

Woodhouse presented *Paleoclimatology and the San Luis Valley*. This was part of a series of monthly talks for the general public, sponsored by the Rio Grande County Museum. Del Norte, Colorado, June 16, 2007.

### **RISA Annual Meeting**

WWA presented two posters presenting current research and projects. WWA personnel attended included Brad Udall, CIRES, Douglas Kenney, NRLC, Chris Goemans, Dept. of Agricultural and Resource Economics, Colorado State University. January 30, 31, San Diego, California.

### **San Francisco Public Utilities Commission Climate Change Summit**

Udall presented *Water Challenges on the Colorado River*, San Francisco, California, January 31, 2007.

### **South Platte Forum**

Goemans presented *South Platte Regional Assessment Tool (SPRAT)*, Longmont, CO, Oct. 25, 2007. Udall presented the keynote speech, '*Moving From Climate Idiots to Savants: Tools for preparing for the coming century of climate.*'

### **Southwest Hydrology and Arizona Hydrological Society 2007 Regional Water Symposium**

Woodhouse presented *Tree Rings and the Colorado River: Lessons from the Past*. Connie This symposium targeted a wide range of water professionals from local, state, and federal government as well as NGOs and academia. Udall presented *Colorado River Basin Climate: What lies ahead? Are there any truths?* These talks were part of a special session convened by Woodhouse and Udall on Colorado River basin hydroclimate, past, present and future. Tucson, AZ, August 30-31, 2007.

**Stegner Center, 12<sup>th</sup> Annual Symposium: The Colorado River Compact in the 21<sup>st</sup> Century: Time for a Change?**, Woodhouse presented *Tree Rings: A Record of Past Flow with Implications for the Future*, This symposium is part of an annual series of symposia organized for the general public by the University of Utah's S. J. Quinney College of Law. Salt Lake City, UT, March 2-3, 2007.



### **Sustainable Water, Unlimited Growth, Quality of Life: Can we Have it All?,**

Kenney presented recent findings from a WWA project that examined the relationship between water demand and pricing, *Residential Water Demand in Aurora, Colorado: Lessons Learned and Remaining Questions*, Tucson, AZ, August 31, 2007.

URL:

[http://wwa.colorado.edu/resources/water\\_demand\\_and\\_conservation/kenney\\_aurora\\_pres\\_en\\_az.pdf](http://wwa.colorado.edu/resources/water_demand_and_conservation/kenney_aurora_pres_en_az.pdf)

**Technical Workshops on Tree-Ring Reconstructions of Streamflow:** Woodhouse and Lukas have held four technical workshops in 2007, providing over 75 water managers and other data users with information about how the tree-ring data and reconstructions of streamflow are generated, the characteristics of these data, and how water entities are successfully incorporating the data into modeling and planning. The WWA Paleo web resource includes web pages for each workshop linked to the presentations.

#### *Workshop Dates, Locations, and URLs*

- May 14, 2007 - Boulder, CO  
URL: [http://wwa.colorado.edu/resources/paleo/boulder\\_workshop\\_2007.html](http://wwa.colorado.edu/resources/paleo/boulder_workshop_2007.html)
- May 31, 2007 - Durango, CO  
URL: [http://wwa.colorado.edu/resources/paleo/durango\\_workshop\\_2007.html](http://wwa.colorado.edu/resources/paleo/durango_workshop_2007.html)
- Sept. 6, 2007 - Cheyenne, WY  
URL: [http://wwa.colorado.edu/resources/paleo/sept\\_2007\\_cheyenne\\_workshop.html](http://wwa.colorado.edu/resources/paleo/sept_2007_cheyenne_workshop.html)
- Nov. 2, 2007 - Albuquerque, NM  
URL: [http://wwa.colorado.edu/resources/paleo/albuquerque\\_workshop.html](http://wwa.colorado.edu/resources/paleo/albuquerque_workshop.html)

### **10th International Meeting on Statistical Climatology (IMSC)**

Wolter gave three presentations: *Observed Temperature Trends in Colorado*, *Monitoring and Defining El Niño/Southern Oscillation Behaviour with an Enhanced Multivariate ENSO Index (MEI)*, and *Seasonal Climate Forecasts for the Southwestern U.S. (a.k.a. "The Catch from Eight Years' Fishing)*. This meeting represents a wide international community, and a unique intersection of statisticians and climatologists, Beijing, China, August 2007.

### **32<sup>nd</sup> Annual Colorado Water Workshop: "Equalizations, Equity and Environment: A Watershed Wide Look at Colorado River Opportunities."**

This workshop sponsored by Western State College, Gunnison, Colorado brings water managers, decision-makers and researchers to address current priority topics in the realm of water management, allocation, and planning. This year, allocation of the Colorado River was examined from an equity point of view as a lens to reexamine current water management practices for future reform and revision. WWA personal in attendance: Christina Alvord, CIRES. Gunnison, Colorado, May 22-24, 2007.

### **University Consortium for Geographic Information Science: 2007 Summer Assembly**

Wolter presented *Global Climate Change: What do we know & don't know?* His presentation focused on climate trends and projections with emphasis on climate



uncertainties provided by IPCC AR4 confidence intervals. The meeting attracted delegates from member institutions from across the United States, representing academia, industry, and government to learn about, and participate in setting future directions for, cutting-edge GIScience research and education. Yellowstone, WY, June 2007.

#### **U.S. Drought Monitor Forum**

Wolter presented *La Niña is back: Drought Prospects in the Western U.S., and the Utility of Improved Climate Divisions*, Portland, OR, October 2007.

#### **U.S. Fish and Wildlife Service**

Udall presented *Water in the West: A Look at the 21<sup>st</sup> Century* in Denver on October 16, 2007.

#### **U.S. Senate, Committee on Energy and Natural Resources**

Udall gave testimony before the U.S. Senate on impacts of climate change on water supplies. Washington D.C, June 6, 2007.

#### **Utah Water Users Association Meeting**

Ray presented an overview of IPCC findings from WG1 and 2, in particular impacts and vulnerability in the Intermountain West. This association represents all Utah water user entities including irrigators, municipal users, industry, federal, state, county and local agencies and private entities. Their annual conference in 2007 was attended by over 150 people, and focused on providing Utah water managers with a background on climate change. [www.utahwaterusers.com](http://www.utahwaterusers.com), Salt Lake City, UT, Dec. 3-5, 2007.

#### **Water Education Foundation Biannual Colorado River Compact Meeting**

Udall provided an overview of the state of Colorado River climate change science to 200 invite-only attendees in Santa Fe September 19-21, 2007.

#### **Water Utility Climate Alliance Meeting**

Udall was the only outsider invited to a meeting September 17, 2007, at Hetch Hetchy, California, attended by the general managers of Seattle, Portland, San Francisco, Metropolitan Water District, San Diego County Water Authority, Las Vegas, Denver, and New York City. He discussed the policy and science of climate change. Udall also provided the attendees with a lengthy memo on these issues.

#### **WGA & Western State Water Council Meeting: Water Policies and Planning in the West: Ensuring a Sustainable Future**

Pulwarty and Webb lead discussion concerning potential adaptation and policy solutions for adapting to a variable climate, Salt Lake City, UT, October 10-12, 2007.

### **Media Interviews/Briefings**

#### **Front Range Water Demand Outreach/Media/Websites:**

- The Western Water Assessment website includes a section devoted to discussion of the Aurora project, [http://wwa.colorado.edu/resources/water\\_demand\\_and\\_conservation/aurora.html](http://wwa.colorado.edu/resources/water_demand_and_conservation/aurora.html);
- A listing of reports and publications from the project, [http://wwa.colorado.edu/resources/water\\_demand\\_and\\_conservation/wwa\\_reports\\_and\\_publications.html](http://wwa.colorado.edu/resources/water_demand_and_conservation/wwa_reports_and_publications.html),
- A Water Demand and Conservation page with links to drought agencies/organizations, municipal drought plans, and reports by other organizations, [http://wwa.colorado.edu/resources/water\\_demand\\_and\\_conservation/demand\\_and\\_conservation\\_links.html](http://wwa.colorado.edu/resources/water_demand_and_conservation/demand_and_conservation_links.html).
- The project was the subject of a newspaper article in the local press: “What Prompts People to Save Water?” Rocky Mountain News, Jerd Smith, October 12, 2007.

**Paleo Climate Information Source:** Connie Woodhouse, University of AZ, Jeff Lukas, INSTAAR

- National Geographic Magazine, February 2008. “Drying of the West” by Robert Kunzig
- National Public Radio; Climate Connections Series, July 29, 2007, “Is Ancient People's End a Warning for the Future?” by Elizabeth Shogren
- Vail Daily, July 8, 2007. “What trees tell us about our weather” by Allen Best.
- American Geophysical Union Joint Meeting, Acapulco, Mexico, press conference, May 23, 2007. Prolonged Drought in the Western US and Mexico in the Context of Long-term Natural Variability, Pacific Ocean Forcing and Climate Warming (Woodhouse: *Perspective from the Colorado River and the Southwest*)

**Dust on Snow Research:** Tom Painter, University of Utah

- “Trouble in Them Thar Hills”, Science Magazine, 12 December, 2007. URL: <http://sciencenow.sciencemag.org/cgi/content/full/2007/1212/3>
- Press Conference, “Climate change in high elevation mountains”, 2007 Fall Meeting of the American Geophysical Union, San Francisco.
- “High Peaks, Dirty Snow”, Forest Magazine, Winter 2008 article focused on Painter group’s dust in snow research written by Allen Best. URL: <http://www.fsee.org/forestmag/1001best.shtml>
- “Ouray Ice Climbing” – The Weather Channel, Epic Conditions, Painter as expert on snow and ice with respect to ice climbing, 2007.
- Reuters News, Nature Magazine, ABC News, LA Times, NY Times, FOX News, Aspen Times, Vail Trail, etc. National and international press coverage on our 2007 paper in Geophysical Research Letters, T. H. Painter, lead author.
- History Channel show on “Snow”, Painter discussing snow hydrology and water resources.
- January, 2007 Backcountry Magazine, quote: "It is hard to appropriately wax for dust"

### **Climate Outlooks and Forecasts: Klaus Wolter, CIRES**

- Regular briefings on climate forecasts and outlooks, regional El Niño/La Niña impacts, storm tracking information, and how unusual various (recent) weather patterns have been with local media outlets including The Boulder Daily Camera, The Denver Post, and Rocky Mountain News, Longmont Times Call, Loveland Reporter Herald, Estes Park Trail Gazette, Evergreen Canyon Carrier, Summit Daily News, Vail Daily, Steamboat Pilot, Montrose Daily Press, etc. (more than half of these contacted at least twice last year). Some of these interviews were prompted by Press Releases / radio interviews through CU (Dirk Martinis their media liaison).
- Interviews with Associated Press (usually the Denver affiliate), Albuquerque Journal, Ski Magazine, Palm Beach Post, Los Angeles Times. Topics regarded recent or expected weather/climate conditions (related to ENSO), but also occasionally about 'Global Change', i.e., temperature trends in Colorado and the apparent relation to pine beetle outbreaks (more over the northern mountains than the San Juans).
- TV& Radio interviews include Denver Channels 2, 4, and 9, KOAA-TV from Colorado Springs, as well as Fox National News, and NPR. Topics ranged from assessment of the recent and expected drought situation in the region, to assessments of the national drought situation, and the threat of climate variability and change to U.S. and European ski resorts.
- U.S. Drought Monitor (together with Gary Bates): repeated comments on drought assessment in Colorado that helped modify weekly USDM maps. This was also in coordination with the Colorado Climate Center, Colorado State Climatologist (Office).
- Monthly conference calls with the Climate Prediction Center (CPC) on monthly and seasonal climate outlooks, which occasionally resulted in their modification of forecasts before public release. These comments focused on the interior southwestern U.S., but often included the rest of the western U.S., including Alaska. In particular, the Drought Outlooks issued by Douglas LeComte (CPC) and published on the USDM web site were often modified to reflect my comments.
- Monthly conference calls or emails with the NIFC (the National Interagency Fire Center). This is mostly related to recent forecasts (<http://www.cdc.noaa.gov/people/klaus.wolter/SWcasts/>).
- Updated SWcasts, which include executive summaries sent to regional media and stakeholders (<http://www.cdc.noaa.gov/people/klaus.wolter/SWcasts/>). Some of these mailings prompted media interviews, but some also preempt them (reporters either gather enough information from the executive summary, or decide that it is a non-story without calling me).

### **New York Times Sunday Magazine**

- Udall and Pulwarty provided extensive briefings for New York Times reporter Jon Gertner who wrote *The Future is Drying Up* in the October 21, 2007 edition of the widely read Sunday magazine.

## **Listserv**

### **Intermountain West Climate Summary e-mail listserv:**

**Stakeholders:** Municipal and agricultural water resource managers, climate researchers, attorneys, policy makers

**Listserv Type:** Monthly e-mail releases

**Listserv Amount:** 357

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## **V. Affiliations with other NOAA Programs**

(Individual contacts in Appendix section)

**Climate Prediction Center:** <http://www.cpc.noaa.gov/>

**Climate Services Division:** <http://www.weather.gov/os/csd/index.shtml>

**National Weather Service (NWS):** <http://www.nws.noaa.gov/>

**Cheyenne, WY WFO:** <http://www.crh.noaa.gov/cys/>

**Salt Lake City, UT WFO:** <http://www.wrh.noaa.gov/slc/>

**Boulder, CO. WFO:** <http://www.crh.noaa.gov/den/>

**Colorado River Basin Forecast Center (CBRFC):** <http://www.cbrfc.noaa.gov/>

**U.S. Drought Assessment:**  
[http://www.cpc.noaa.gov/products/expert\\_assessment/drought\\_assessment.shtml](http://www.cpc.noaa.gov/products/expert_assessment/drought_assessment.shtml)

**National Integrated Drought Information System (NIDIS):** <http://www.drought.gov>

**National Drought Mitigation Center:** <http://drought.unl.edu/>

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## **VI. Current Cross-RISA Activities**

The regional focus of the RISAs has been critical to their success. However, when a climate-related problem exceeds the existing regional boundaries, involves all RISAs, or can easily scale expertise and solutions developed in one region for use in another, the program need to acknowledge and promote these opportunities. The following are our current areas involving cross-RISA collaboration.

**Drought: Tree-Ring Reconstructions of Hydroclimatic Variability in the Rio Grande Basin,** New Mexico (Connie Woodhouse, University of Arizona/WWA; Brad Udall, University of Colorado/WWA; Deborah Bathke, New Mexico State University/NM Assistant State Climatologist/CLIMAS, Gregg Garfin, University of Arizona/CLIMAS) with Holly Hartman (UA/CLIMAS).

The goal of this cross RISA paleoclimatology project is to expand and improve the usability of tree-ring based reconstructions for drought planning and resource management in the Rio Grande basin. The end result of this project will be a new set of stakeholder partnerships in New Mexico, a set of preliminary hydroclimatic reconstructions for the Rio Grande basin, and an online paleodrought resource, modeled after the Colorado TreeFlow web site, for New Mexico, with a framework for additional regions. A primary component of this project is the two stakeholder workshops, one of

which was held in Albuquerque in November 2007, and the second to be held in May 2008.

**Developing Hydroclimatic Reconstructions for Water Resources Management in the Pacific Northwest**, (SARP-funded project) (Nate Mantua, Jeremy Littell, and Alan Hamlet from CIG and WWA collaborator, Connie Woodhouse)

The geographic focus of this project is the Pacific Northwest US (PNW). The work for this project consists of: (1) development of a network of tree-ring chronologies sensitive to both winter and summer precipitation, (2) streamflow reconstructions for gages of importance to water resource managers; and (3) a vulnerability assessment of streamflow supply given changes in future mean climate and past variability. The tree-ring networks will take advantage of recent methodological advances in PNW dendroecology and dendroclimatology developed by Co-PI Littell and be informed by PI Mantua's conceptual basis for scaling up from local to hemispheric climate variability. The vulnerability assessment will incorporate sophisticated hydrological modeling to develop several future streamflow scenarios which will be used in conjunction with retrospective drought reconstructions to produce forecasts of drought under 21st century climatic conditions. Two workshops will be convened with PNW water providers to identify reconstruction targets and critical information as well as to investigate ways they might use these reconstructions in water resource planning and management. The first workshop would focus on developing our understanding of the regional needs for climate information by water managers and planners. The second workshop would focus on the results of the reconstructions and modeling products from goals one and two and developing ideas about barriers to building adaptive capacity and decision support tools useful for western Cascades municipal water supply and on the use of the mid-size agricultural basin reconstructions for water supply forecasts and storage analyses at larger scales. This is a two-year project, begun in summer 2007.

**Colorado River:** See Reconciling Colorado River Flows, Section III, page 8.

**National Climate Service Scoping:** The RISAs need to be active in providing a unified vision for this critical need. WWA is taking a lead in organizing this activity.

**Climate Summary collaboration:** The WWA Intermountain Climate Summary was modeled after the CLIMAS Southwest Climate Outlook. We share articles and expertise and will continue to do so in the future.

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## VII. Other Projects

### Colorado Temperature Trends

**PI's:** Klaus Wolter, CIRES-NOAA, Nolan Doesken, Colorado Climate Center, Colorado State University

Research on Colorado temperature trends in collaboration with Nolan Doesken (CO State Climatologist). Findings suggest that warming trends have been most pervasive in the north-central mountains, and much less so on the eastern plains of Colorado (in the last few decades). We are still sorting out some issues with meta-data discrepancies (some obvious step changes in the observed record do not match up with instrument/station-move/observer changes). We are also still attempting to sort out which stations are affected by 'urban heat island' issues vs. 'land-use changes' (especially irrigation). We aim to get this wrapped up in 2008.

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## VIII. Appendix

### Publications

**\*= communicated to decision makers**

#### **Peer Reviewed (submitted or in preparation):**

- Alvord, Christina, P. Long, R. Pulwarty, and B. Udall. Climate and Tourism on the Colorado Plateau. *Bulletin of Meteorological Society*, May 2008. (Accepted November 2007).
- \*Howe, Charles W. and Christopher Goemans, 2007. The Simple Analytics of Demand Hardening, *Journal of American Water Works Association (JAWRA)* 99(10).
- Kenney, Doug, 2007. Book Review of *Drought and Water Crises* (by Donald Wilhite). *Bulletin of the American Meteorological Society*, September.
- \*Kenney, Doug, Christopher Goemans, Roberta Klein, Jessica Lowrey, and Kevin Reidy, 2008. Residential Water Demand Management: Lessons from Aurora, Colorado. *Journal of the American Water Resources Association (JAWRA)* 44(1):192-207.
- Malenovsky, Z., H. M. Bartholomeus, F. W. Acerbi-Junior, J. T. Schopfer, T. H. Painter, G. F. Epema, and A. K. Bregt, Scaling dimensions in spectroscopy of soil and vegetation, *International Journal of Applied Earth Observation and Geoinformation*, 9, doi:10.1016/j.jag.2006.08.003.
- \*Meko, D.M., C.A. Woodhouse, C.H. Baisan, T. Knight, J.J. Lukas, M.K. Hughes, and M.W. Salzer, 2007. Medieval drought in the upper Colorado River basin. *Geophysical Research Letters* 34m L10705, doi: 10.1029/2007GL029988.
- Meko, D.M. and C.A. Woodhouse, in press. Dendroclimatology, dendrohydrology, and water resources management, In: *Tree Rings and Climate: Sharpening the Focus*, (eds. H.F. Diaz and M.K. Hughes). Kluwer/Springer.
- Painter, T. H., N. Molotch, M. Cassidy, M. Flanner, and K. Steffen, Contact spectroscopy for the determination of stratigraphy of snow grain size, *Journal of Glaciology*, 53(180), 121-127.
- \*Painter, T. H., A. P. Barrett, C. Landry, J. Neff, M. P. Cassidy, C. Lawrence, K. E. McBride, and G. L. Farmer, Impact of disturbed desert soils on duration of mountain snow cover, *Geophysical Research Letters*, 34, L12502, doi:10.1029/2007GL030284.
- Scambos, T., T. Haran, M. Fahnestock, T. H. Painter, and J. Bohlander, MODIS-based Mosaic of Antarctica (MOA) data sets: Continent-wide surface morphology and snow grain size, *Remote Sensing of Environment*, 111(2-3), 242-257.

## **Other Publications and Working Papers (Not peer reviewed)**

### **Front Range Water Demand**

\*Kenney, Doug, Christopher Goemans, Roberta Klein, Jessica Lowrey, and Kevin Reidy, 2007. Residential Water Demand Management in Aurora: Lessons from the Drought Crisis, Colorado Water, February/March.

Klein, Roberta, Doug Kenney, Jessica Lowrey, and Christopher Goemans, 2007. Factors Influencing Residential Water Demand: A Review of the Literature (working paper located at:

[http://wwa.colorado.edu/resources/water\\_demand\\_and\\_conservation/literature\\_review\\_version\\_1\\_12\\_07.pdf](http://wwa.colorado.edu/resources/water_demand_and_conservation/literature_review_version_1_12_07.pdf)

### **Paleo Climate**

\*Woodhouse, C.A., J. J. Lukas, and D. M. Meko, in press. Reconstructions of Colorado River Flow from Tree Rings. In CADWR Drought publication (J. Jones, Ed.).

### **Native Communities and Climate Change**

\*Hanna, J. and M. Squillace, 2007. Native Communities and Climate Change: Legal and Policy Approaches to Protect Tribal Legal Rights.

### **Water Rights and Climate Change Project**

Articles available at:

[http://wwa.colorado.edu/current\\_projects/water\\_rights\\_climate\\_change.html](http://wwa.colorado.edu/current_projects/water_rights_climate_change.html)

Kenney, Douglas, Roberta Klein, Chris Goemans. 2007 Climate Change and the Functioning of Water Rights: Results of Literature Search.

Kenney, Douglas, Roberta Klein, Chris Goemans, Christina Alvord, 2007. The Effect of Changing Hydrographs on Interstate Apportionments.

Kenney, Douglas, Roberta Klein, Chris Goemans, Christina Alvord, 2007. The Growing Mismatch Between the Timing of Spring Snowmelt and Diversion Schedules Specified in Prior Appropriation Water Rights: A Preliminary Overview and Comparison of Circumstances in the Western United States.

Klein, Roberta, 2007. Colorado Water Rights Basics.

### **Intermountain West Climate Summary:**

January 2007- December 2007 Editions including Feature (FA) and Focus Articles (FP):

January 2007

FA: *Climatic and Hydrologic Trends in the Western U.S.: A Review of Recent Peer-Reviewed Research*, by Brad Udall of Western Water Assessment and Gary Bates of NOAA Earth System Research Lab

FP: *Assessing Water Supply Conditions for Utah*, by Brian McInerney of NWS Salt Lake City Weather Forecast Office and Christina Alvord of Western Water Assessment

March 2007

FA: *Drought, Climate Variability & Change, and Potential Impacts on Wyoming's Water Resources*, by Stephen Gray, WY State Climatologist and Director of Wyoming's Water Resources Data Center, with Christina Alvord of Western Water Assessment  
FP: *Assessing Water Supply Conditions for Southeast Wyoming in 2007*, by Melissa Goering, Science Operations Officer, NOAA National Weather Service Weather Forecast Office, Cheyenne, Wyoming

April 2007

FA: *Technical Workshops for Water Managers on Tree-Ring Reconstructions of Streamflow*, by Jeff Lukas, University of Colorado and Western Water Assessment, and Connie Woodhouse, University of Arizona and Western Water Assessment

FP: *The Colorado Climate Center*, by Nolan Doesken, Colorado State Climatologist

May 2007

FA: *Recent Research on the Effects of Climate Change on the Colorado River*, by Brad Udall, Western Water Assessment

FP: *New National Weather Service Western Water Supply Forecast Services*, by Christina Alvord, Western Water Assessment, and Kevin Werner, NWS Water Resources Hydrology Science Program

June 2007

FA: *New Climate Divisions for Monitoring and Predicting Climate in the U.S.*, by Klaus Wolter and Dave Allured, University of Colorado at Boulder, CIRES Climate Diagnostics Center, and NOAA-ESRL Physical Sciences Division

FP: *Climate and Tourism on the Colorado Plateau: A Workshop Summary*, by Christina Alvord, Western Water Assessment, Patrick Long, Leeds School of Business, University of Colorado, Roger Pulwarty, NOAA, and Bradley Udall, Western Water Assessment

July 2007

FA: *Drought Indices*, by Michael Hayes, Associate Director, National Drought Mitigation Center, with Christina Alvord and Jessica Lowrey, WWA

FP: *Climate Prediction Center Soil Moisture Products*, Jessica Lowrey, WWA

September 2007

FA: *Drought, Wildfire, and Climate Connections: Research in Forests of the Western U.S.*, by Jessica Lowrey, WWA

FP: *The U.S. Hazards Assessment Program*, by Christina Alvord, WWA, and Edward O'Lenic, Climate Prediction Center

November 2007

FA: *Impacts, Adaptation and Vulnerability: A Summary of the Report from IPCC Working Group 2 and Implications for the Western U.S.*, by Andrea Ray, NOAA Earth System Research Laboratory and the Western Water Assessment

FP: *Overview of the Western Water Assessment's Water Rights and Climate Change Project*. Researchers Douglas Kenney (CU Natural Resource Law Center), Bobbie Klein



(CU Center for Science and Technology Policy Research), Chris Goemans (CU Department of Agricultural and Resource Economics), and Christina Alvord (WWA).

## **Personnel with Direct Interest in WWA**

CIRES/Other CU (Funded directly by WWA)

Brad Udall, Director, CIRES  
Christina Alvord, CIRES  
Chris Anderson, CIRA (not funded 2007)  
Joe Barsugli, CIRES (not funded 2007)  
Chris Goemans, CSU  
Jess Lowrey, CIRES  
Eileen McKim, CIRES  
Julie Malmberg, CIRES  
Tom Painter, University of Utah  
Klaus Wolter, CIRES  
Jon Eischeid, CIRES  
Balaji Rajagopalan, CIRES  
Doug Kenney, University of Colorado  
Bobbie Klein, CIRES  
Edie Zagona, University of Colorado  
Jeff Lukas, University of Colorado

Active NOAA Personnel (Not funded)

Andrea Ray  
Robin Webb  
Roger Pulwarty  
Marty Hoerling

Official PIs (Not funded)

Koni Steffen, CIRES  
Randy Dole, NOAA

Unofficial PI (not funded)

Susan Avery, WHOI

Hydrosphere Resource Consultants (funded)

Ben Harding  
Subhrendu Gangopadhyay

## **Current WWA Projects By Temporal Focus**

### **1. Paleoclimate**

- Workshops and Support (web page resources) for Water Managers (Woodhouse, Lukas)
- Non-parametric Paleoclimate Reconstructions (Jointly Funded with Reclamation–Hydrosphere, Lukas, Woodhouse, Balaji)

- Paleo Climate in the San Juans with Mountain Studies Institute (also Fort Lewis College) (Woodhouse, Lukas)
- New Reconstructions for the Upper Colorado River Basin (Woodhouse, Lukas, Meko)
- Paleo Perspective on the Colorado River web site (Woodhouse, Lukas, Meko)
- Evaluation of the use of Tree-Ring data in Water Resource Management (Woodhouse, Lukas, Rice)

## 2. Seasonal to Interannual

- Intermountain Climate Summary (Ray, Lowrey, Alvord, McKim)
- WATF Support Water Availability Task Force: Seasonal Forecasts (Wolter)
- Runoff Forecasting for Water Managers (Jointly Funded with Denver, Aurora, CSprings, Boulder)
- Impacts of Dust on Snow (Painter)
- New Climate Divisions (Wolter)
- MEI Enhancement (Wolter)

## 3. Climate Change

- Colorado River Climate Support for Reclamation (Webb, Hoerling, Udall, Ray, others)
- Citizen's Guide to Climate Change (Udall, Pulwarty) for Colorado Foundation for Water Education
- Colorado Temperature Analysis (Wolter, Doesken)
- Impacts of Dust on Snow (Painter) comment: cross listed above.
- Native Americans and Climate Change (with Natural Resources Law Center, Alvord, Kenney)
- CCSP SAP Support
  - 3.1 Modeling (Review, Udall)
  - 3.3 Extremes (Pulwarty)
  - 5.3 Decision Support (Webb, Pulwarty)
  - Unified Synthesis Product (Udall, Pulwarty)
- Special Technical Report on Climate Change and Water (Pulwarty)
- IPCC WG2 – Pulwarty
  - Adaptation Practices Chapter
  - Water Chapter
  - Rocky Mountain IPCC Summary

## 4. Cross-Scale Activities

- Front Range Water Demand (Kenney, Goemans, Klein, Lowrey)
- Colorado River Severe Sustained Drought Follow-On (OGP HD/SARP Funded, Kenney, Ray)
- NIDIS Support (Alvord, others)
  - Likely Colorado River Pilot Project
- User Needs Assessment for Front Range Water Providers (Ray, Lowrey)
- National Interagency Fire Center Conference Support (Wolter, others)

- Tourism and Climate Conference (Pulwarty, Udall, Long, Alvord)
- Colorado River Adaptive Management (Pulwarty, Jain)
- Various NOAA Committees served by WWA
- Estimating the economic impacts of drought (Wilhite, Pulwarty, Hayes, Howe, Supallam Chermak, Eischeid) This is a SARP and USDA Risk Management Agency project
- Gunnison EIS Streamflows (Rajagopalan, Ray)

#### 5. Outreach and Education

- Front Range Climate Change Workshop
- Speakers' Bureau
- Web Presence
- Intermountain Climate Summary (cross-listed above, too)
- Experimental Seasonal Forecast Guidance and related media outreach (cross-listed above, too)
- ENV5 Class, 5810, Water Resources and Environmental Sustainability

### **Recurrent Individual Contacts (alphabetical by organization or stakeholder category)**

#### **Climate Prediction Center, NOAA**

V.E. Kousky: [Vernon.Kousky@noaa.gov](mailto:Vernon.Kousky@noaa.gov)  
 Michelle L'Heureux: [Michelle.LHeureux@noaa.gov](mailto:Michelle.LHeureux@noaa.gov)

#### **Climate Services Division, NOAA**

Diana Perfect: [Diana.Perfect@noaa.gov](mailto:Diana.Perfect@noaa.gov)  
 Bob Livezey: [Robert.E.Livezey@noaa.gov](mailto:Robert.E.Livezey@noaa.gov)  
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