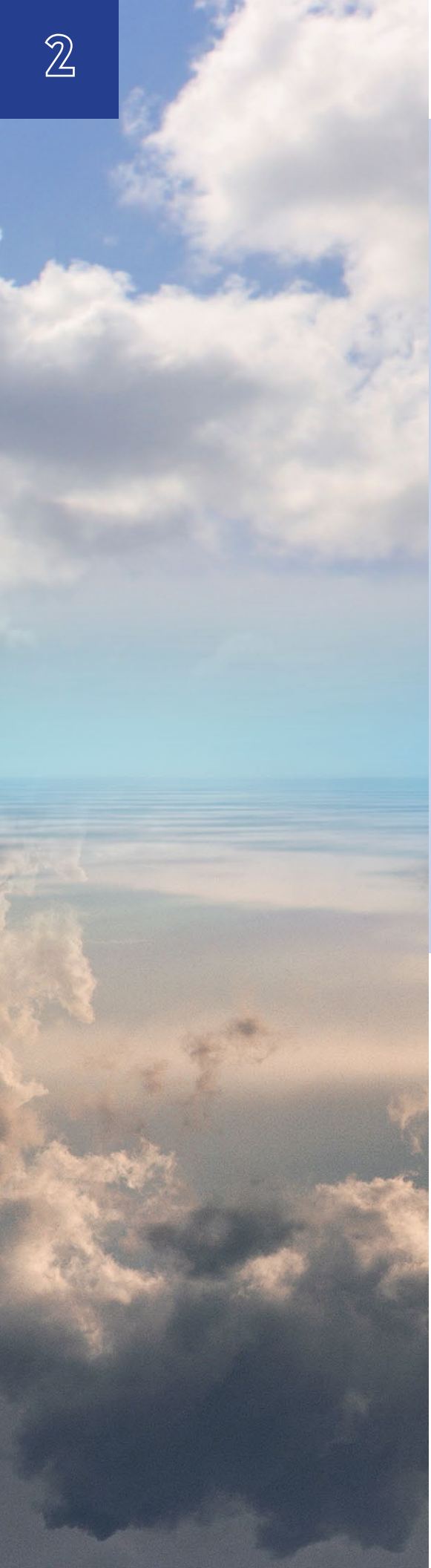
Linking Climate Change Science to Water Management Decisions

by Gary Pitzer, Water Education Foundation



Editor's Note:

This special publication was produced by the Water Education Foundation to provide the public with information on one of the key steps in climate change research: how to adapt to changing climate conditions and how to plan for those conditions. Much of the content of this publication is based on presentations at the 8th Annual Climate Prediction Applications Science Workshop (CPASW) held March 2-4, 2010, in San Diego. The conference, "Managing Water Resources and Drought in a Changing Climate", was sponsored by the National Oceanic and Atmospheric Administration's (NOAA) National Weather Service Climate Services Division, California Department of Water Resources (DWR) and National Integrated Drought Information System. It was cosponsored by the Water Education Foundation.

The mission of the Foundation, an impartial, nonprofit organization, is to create a better understanding of water resources and foster public understanding and resolution of water resource issues through facilitation, education and outreach. Climate change is one of the most important issues facing water resource managers today and decisions will need to be made about how to adapt to these changing climate conditions. We believe this publication will help you better understand these challenges.

– Rita Schmidt Sudman, Executive Director, Water Education Foundation

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Introduction

While reams of information have been produced about the advent of climate change and its across-the-board impacts, water users are still struggling to find the right way to incorporate anticipated changes into their planning.

The task is far from easy and apparently still very early in its development.

"Adaptation is a relatively new concept in California policy," states the California Natural Resources Agency's 2009 *Climate Adaptation Strategy*. "The term generally refers to efforts that respond to the impacts of climate change – adjustments in natural or human systems to actual or expected climate changes to minimize harm or take advantage of beneficial opportunities."

Applying current science to planning by water utilities is a challenge because long-held assumptions about weather and hydrology are being revisited and because there is as yet a limited connection between experts and water utility managers.

"Initially, we thought if we could just talk to climate scientists and tell them what our needs are they could fix it," said Lorna Stickel, water resources planning manager with the Portland Water Bureau. She was among a host of scientists, water utility personnel and local and federal agency officials at the "Climate Prediction Applications Science Workshop" held March 2-4, 2010 in San Diego. The workshop was sponsored by the National Oceanic and Atmospheric Administration's (NOAA) National Weather Service Climate Services Division, California Department of Water Resources (DWR) and National Integrated Drought Information System. It was cosponsored by the Water Education Foundation.

The bridge between knowledge and applicability is slowly being crossed, with the acknowledgement that much territory remains to be crossed before water utilities can fully plug in the means by which changing precipitation variability and extreme events can be accounted for. While some skepticism remains about climate change, government officials say the issue is being directly confronted to develop adaptation strategies.

Climate services "is of high visibility and high importance to the [Obama] administration," said Eileen Shea, chief of the Climate Services and Monitoring Division at the National Climatic Data Center in Asheville, N.C. "There is an increasing demand for how climate change affects lives, public health and safety, national security and resource management."

The increase in demand for information has not been correlated by an adequate response by scientists to water users and the public. Shea said her agency "recognizes that it isn't currently optimized" to deliver services to meet the demand and that one of NOAA's main objectives is "providing easily accessible, easily understandable information about climate change as it relates to water, energy and jobs."

Water managers who depend on scientists' forecasts to plan their operations have not been encouraged thus far by the pronounce-

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– Jeanine Jones, DWR

ments about climate change and its probable impacts. The studies have been varied in their scope and range of predictions, leaving officials vexed regarding what the changes mean to them and how they should respond.

"A lot of work needs to be done on the science side," said Jeanine Jones, interstate resources manager with DWR and a member of NOAA's Climate Working Group. "Sooner or later we hope science will give us more certainty."

John Andrew, assistant deputy director at DWR, said there is room for improvement because "we are asking locally elected boards of directors to make decisions based on science and I don't think in all cases the certainty is there."

Jones said the discussion needs to be broadened to bring state and local officials into the mix. "Right now, it's NOAA talking to NOAA and to the academic research community, not the users," she said.

Those in charge of supplying water are often engineers and "typically don't have a disciplinary background in climate science," Jones said. "We tend to be a fairly conservative bunch as a whole; we have public safety in mind first and foremost. We live and work in a very litigious environment. The challenge is to incorporate science that comes with relatively high levels of uncertainties into traditional water infrastructure management."

Jones' colleague, State Climatologist Michael Anderson, said a "hybrid entity" is needed to act as a go-between for scientists and water agencies, with an "I-know-it- when-I-see-it" person who can make the connection between climate change and agency functions. It is "an open question" how climate change affects water supply forecasts, he said.

What is known is that system reoperation "is scales of flood management vs. scales of water supply management," Anderson said, adding the "question is, how do you test for this and evaluate" results. What is without question is "the way we do things now is not going to work" and that "how we change is the next step in the process."

What the change will look like is not easy to envision. The rim reservoirs upon which California's water supply depends are not obligated to operate any differently beyond their downstream boundary, Anderson said, adding that defining system reoperation and finding willing participants in reoperation experiments are questions that "remain to be answered."

"It's a big challenge and should be quite an interesting ride," he said.

Throughout the three-day workshop, scientists presented an array of evidence about climate change. Experts say there are detectable changes in stream flows that portend more frequent extreme events and that there is a linkage from anthropogenic contributions such as land development.

"The signals of climate change are emerging in the West over broad footprints," said Dan Cayan, researcher with the Scripps Institute of Oceanography in La Jolla. "Accumulated snowpack and temperature is trending toward less

snow and more rain over the last couple decades."

Cayan said a "cascade of evidence" is leaning toward the conclusion that the changes being seen are attributable to climate change. "The models are saying we are just seeing the first signs of this," he said.

The Colorado River Basin "stands out as one of the more sensitive areas in the West to climate-induced runoff," Cayan said, noting that an overall warming of one degree Celsius causes a 6 percent decline in flow in the aggregate river.

"We are finding ourselves in climates we have not experienced in at least the last 1,000 years," Cayan said.

Scientists at the workshop explained that temperature and precipitation is where "sensible" climate is expressed and that work now is geared toward looking probabilistically beyond the traditional six-to 10-day and eight-to 14-day outlooks.

"You don't understand climate change unless you understand the processes that are driving it," said Tim Schneider, physicist with NOAA's Earth System Research Laboratory in Boulder, CO. "It's a problem of too much water and too little water."

The atmospheric "rivers" that carry storms are warmer, with higher rain levels. Consequently, storms are "warmer and wetter," he said.

NOAA has made "great strides" in precipitation forecast but there remain "a lot of challenges" in defining extreme events like flood and drought, Schneider said, noting "if there's no confidence, there's no credibility."

The *Climate Adaption Strategy* warns "the cost could be severe" if no action is taken to reduce or minimize future climate change impacts, particularly from sea level rise and greater threat of wildfires. "As the climate changes, so must California," the report says. "To effectively address the challenges that a changing climate will bring, climate adaptation and mitigation policies must complement each other and efforts within and across sectors must be coordinated. For years, the two approaches have been viewed as alternatives, rather than as complementary and equally necessary approaches."

Adapting to climate change "is as important if not more important" for the water sector than anywhere else, Andrew said. DWR is trying to bring adaptation and mitigation into some balance, he said, and the emphasis on integrated regional water management (IRWM) "is the frontline defense" against an uncertain future.

IRWM aims to improve long-term water supply reliability within California by recognizing the inter-connectivity of water supplies and the environment, and then pursuing projects yielding multiple benefits for water supplies, water quality and natural resources.

"It's not one-size-fits-all and that's what makes it work so well," Andrew said.

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Stationarity is Dead

Climate change is reflected, among other ways, by temperature readings. Numerous completed and ongoing studies are strictly geared toward all aspects of temperature measurements and their implication to the environment. Kelly Redmond, regional climatologist with the Western Regional Climate Center in Reno, Nev., said the last 10 consecutive years have seen above average temperatures in California, with a notable increase in the average minimum temperature. The level at which freezing occurs has increased by as much as 500 feet the past 25 to 30 years.

Putting the phenomenon in context can be a challenge, however. The warmest day on average globally occurred even as Washington, D.C. was hit with record-breaking snow. "What you see out the window doesn't always reflect what's going on around the globe," Redmond said.

While there is "nothing new" about the occurrence of extreme weather events, what is new are the recent predictions that future occurrences will be more extremes, "perhaps invalidating … assumptions" about stationary weather patterns, said Soroosh Sorooshian, distinguished professor at the University of California, Irvine. Those extremes will present adaptation and mitigation challenges because of the heavy rain and rapid snowmelt, he said, adding the other extreme will be more intense drought.

"Traditionally, water resource planning has used recorded weather and hydrology to represent future supply conditions [and] it was assumed that the hydrologic determinates of future water resources – temperature, precipitation, streamflow, groundwater, evaporation, and other weather-dependant factors – would be the same as they had been in the past," states a 2010 report by the Water Utility Climate Alliance (WUCA), *Decision Support Planning Methods: Incorporating Climate Change Uncertainties into Water Planning*. "While there may have been large variations in observed weather, it was assumed that weather statistics would stay the same and variability would not increase in the future. This core planning assumption is often referred to as *climate stationarity*."

As described in a February 2008 *Science* magazine article, "Stationarity Is Dead: Whither Water Management?" stationarity is no longer valid "because substantial anthropogenic change of Earth's climate is altering the means and extremes of precipitation, evapotranspiration, and rates of discharge of rivers."

"Stationarity is less alive than we thought it was," said Robert Hartman, hydrologist in charge with the NWS in Sacramento. The increased variability of events "is more dangerous than climate change [because] it's the increased variability of extremes that'll get you," he said.

Because stationarity "should no longer serve as a central, default assumption in water-resource risk assessment and planning, finding a suitable successor is crucial for human adaptation to changing climate," the *Science* article says. Because stationarity "cannot be revived," and because "even with aggressive mitigation, continued warming is very likely," scientists need to figure out alternative probabilistic models "and to use those models to optimize water systems."

"The challenge is daunting," the article says. "Patterns of change are complex; uncertainties are large; and the knowledge base changes rapidly."

Cayan said "a lot of trickiness needs to be worked out" in understanding how evapotranspiration measuring devices work and that it is beneficial to look at several models to ensure a degree of accuracy. Generally speaking, "the highest sensitivities" exist in the transition areas between rain and snow, he said.

"Handling the topography and hydrology is very critical," Cayan said. "If not done properly, you get a distorted view of the hydrology and how the resulting flow responds."

An overall temperature increase of 2 degrees Celsius is expected across the Colorado River Basin between 2050 and 2099, which would result in a decline in flow of 10 to 20 percent and not the 50 percent that was first reported.

WUCA's December 2009 report, *Options for Improving Climate Modeling to Assist Water Utility Planning for Climate Change*, noted that "in general, WUCA members prefer to have climate model projections at the same space and time scales as their system models to best capture physical processes and operations associated with their supplies."

The report says "there does not appear to be a single investment – i.e., the proverbial 'magic bullet' – which will substantially reduce the range of projections at the scale at which utility planning is conducted," and that "only modest progress is expected because two main sources of uncertainty – emissions scenarios and model climate sensitivity – have seen only slow progress in narrowing uncertainty."

Hydrometeorology

Meanwhile, for more than a decade, scientists have studied hydrometeorology in Northern California's American River watershed. Aimed at gauging the exact impact of changing conditions on the watershed, the practice uses an array of monitoring devices to determine the extent to which flow conditions are changing, the effect of fluctuating runoff peaks and how the snow line is slowly retreating upward.

"The research is just coming to a really productive place and now is the time to involve stakeholders," said Michael Dettinger, resident hydrologist with USGS in La Jolla.

The American River research has yielded data indicating a string of high-flow years that have come since the construction of Folsom Dam in 1955. The dam was engineered during a time of lower peak flows, setting the stage for potentially disastrous consequences. "We are really in position to have our own [Hurricane] Katrina in California," Dettinger said.

To buttress existing forecasting and warning networks, Dettinger said "offshore reconnaissance" will eventually be needed to protect vulnerable areas from the adverse impacts of extreme storm events. Also needed is a "serious state level soil moisture monitoring network" that could be co-located with the existing California Irrigation Management Information System. "We're also working on building a network to keep track of how much water vapor is pouring into the state during our winter storms," he said. "This isn't a pipe dream; we've already retrofitted [Global Positioning System] sensors to keep track of this at 15 sites this year."

Dettinger said the American River hydrometerological research is a "great example" of NOAA's Climate Research Program "leaving behind a legacy at the local level," that is now being expanded to cover the entire state.

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Adaptation

"Climate change is challenging the way water utilities plan for the future," WUCA's 2010 report says. "As water utilities grapple with preparing for the large range of possible climate change impacts, many are searching for new planning techniques to help them better prepare for a different, more uncertain, future."

Water utility adaptation to climate change means "preparing for a wide range of possible impacts," using planning methods that "consider multiple future conditions to incorporate more and greater uncertainties into the water planning process. This can be useful not only in planning for climatic uncertainty, but also in planning for uncertainty about regulatory, environmental, economic, social, and other conditions affecting water utilities," the report says.

In California, where the value of water is well-known, the message is loud and clear that maximizing the efficiency of every drop is crucial. For years, DWR and others have touted the benefits of water conservation and the lengths to which cities, farms and businesses can go to reach even greater savings. While advances have been made, "there is much potential to be seen" in improving water use efficiency, Andrew said.

Overall, however, the state has "bad habits" in its water management, such as the disconnect between groundwater and surface water, the separation of water supply from flood management and the ecosystem and the fact that all are separated from land use planning, Andrew said. Finding a solution to the problems of the Sacramento-San Joaquin Delta is especially important because it is "probably the region most affected by climate change."

Improving water management decision-making "is the most important thing we can do [but] also the hardest thing because there is no natural constituency to do this," Andrew said, adding that "nobody runs [for office] saying 'I'm for more data, vote for me.'" Furthermore, the state can't address the sustained, long-term threat posed by climate change "by lurching from one bond measure to another."

Andrew said that while it may be unclear how climate change will affect water management, "we do know what stressors are there now," and if those stressors can be reduced, it gives water managers a "sporting chance" to deal with climate change in the future.

"We think adapting will probably be the biggest challenge to water sector right next to population growth," he said. "We will have to embrace a new strategy for water resource management."

Moving forward in the face of uncertainty requires water utilities to understand model projections, assess their vulnerabilities and plan and incorporate climate change uncertainty into decision making. "If you can't coalesce around a few key messages that will resonate with people, then you are finished," said Stickel with the Portland Water Bureau. "You have to make it a real message without over blowing it."

Part of the challenge is interpreting and presenting climate change data in a way that's meaningful and

practical. Broad scientific data such as temperature measurements across decades "doesn't tell you a lot about wheat in Nebraska," said Derek Arndt, physical scientist with the NOAA's National Climatic Data Center in Asheville, N.C.

Much of the time, attention is focused on the biggest weather event of the moment, even while other regions are experiencing conditions related to climate change. "One of our challenges is to not get attracted to the 'ball' but to maintain a climate-wide view," Arndt said. "Climate monitoring doesn't happen in one building. It happens everywhere."

Using the analogy of the 1976 film "Rocky," he said climate should be thought of as Mickey the trainer while weather is Rocky the boxer.

"Weather is what punches people in the gut," Arndt said. "Climate change changes the character and frequency of those punches."

Arndt characterized climate change as the question of "how often is weird stuff happening and how weird is it?" Climate change impacts society by affecting crop moisture, temperature and energy use, air stagnation and through "billion-dollar disasters," he said. He mentioned NOAA's Northeast Snowfall Impact Scale that characterizes and ranks high-impact Northeast snowstorms. Tracking storms with large areas of 10-inch snowfall accumulations and greater, the scale has five categories: extreme, crippling, major, significant and notable.

"This scale was developed because of the impact Northeast snowstorms can have on the rest of the country in terms of transportation and economic impact," according to NOAA.

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Priorities

Participants at the workshop said the linkage between climate change science and its applicability to water users has to be developed through "user engagement," with users driving the process. They suggested a "product forum" be developed that would allow users to register with and give feedback on the devices and techniques that exist to bridge the gap between science and its practical application. Those products must be "trusted, realistic and timely," according to workshop participants.

Furthermore, those in the user community need to be aware of what the research is and that researchers need to be aware of users needs. "A lot of partnerships need to be regionally built rather than institutionalized at the national level," said Robert Webb, research scientist in NOAA's Office of Atmospheric Research, Earth System Laboratory. "Partnerships must be built around specific questions."

California's ability to deal with climate change impacts "depends on a number of critical factors," such as funding, technological development, effective governance, public awareness, leading scientific information and "equity in access" to natural resources, according to the *Climate Adaption Strategy*, which notes "the state has the ability to strengthen its capacity in all of these areas."

Meanwhile, the process of bringing climate change science and its meaning to the local level continues, where officials sometimes have to press ahead with water management in the face of uncertainty. "It's important to bring people like myself more knowledge of climate change," said Mark Hampson, a civil engineering associate with the Los Angeles Department of Water and Power. "While we are not the ones making decisions we are the ones writing the memos and giving the presentations."

The workshop presentations and summary documents are available at www.joss.ucar.edu/events/2010/cpasw/agenda.html