Workshop on Improving Sub-Seasonal and Seasonal Precipitation Forecasting for Drought Preparedness

May 2015 | San Diego

Cover photo:
Aerial view of extremely low water (drought) conditions at Lake Don Pedro.

Proceedings of the
Western States Water Council/
California Department of Water Resources

Workshop on Improving Sub-Seasonal and Seasonal Precipitation Forecasting for Drought Preparedness

May 2015 | San Diego

Acknowledgements

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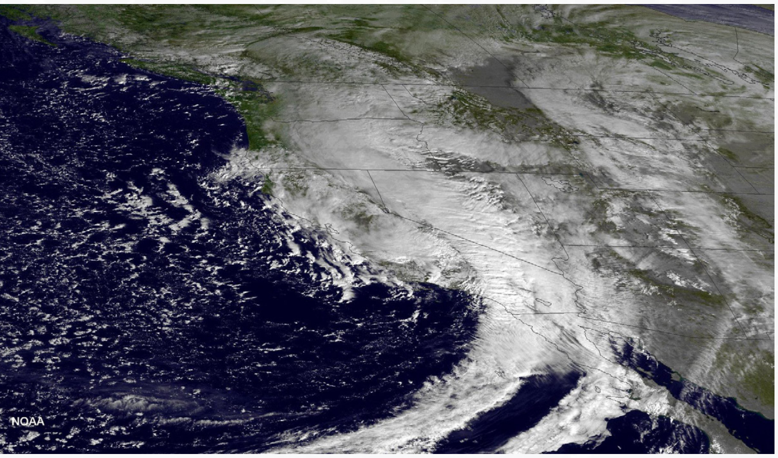
INTRODUCTION

Skillful sub-seasonal (monthly) to seasonal (the water year) precipitation forecasting would support many facets of water management, providing lead time for preparing for extreme events and allowing for more efficient operation of water infrastructure. Current forecast practices and scientific capabilities for making skillful forecasts beyond the weather time domain, however, are limited.

The Western States Water Council (Council) has urged that the federal government place a priority on improving monthly and seasonal forecasting capability to support water management decision-making. The National Oceanic and Atmospheric Administration's (NOAA's) service assessment in 2014 for the 2012-2014 California drought identified the high importance that water managers and users place on improving (and using) seasonal precipitation prediction at the watershed scale. Great improvements in forecast skill have been made for weather forecasts over the past decades, but similar progress has not been made in monthly to seasonal forecasting. Weather models are run operationally out to two weeks ahead, although they are most skillful for timeframes of less than five days. Apart from simply predicting that historical climatology will recur, presently most skill in operational sub-seasonal to seasonal forecasting methods comes from El Niño Southern Oscillation (ENSO) conditions – if an ENSO signal is present and for a geographic region where ENSO may provide some predictive guidance.



The primary source for monthly to seasonal forecasts is NOAA's Climate Prediction Center (CPC), which produces national-scale outlooks for temperature and precipitation (e.g., 30-day outlook, and seasonal outlooks for each three month season out to one year into the future). CPC's outlooks only make a forecast for the geographic areas in which they have skill at the time of the forecast; "equal chances" forecasts are made for other areas. While progress in improving skill of near-term climate forecasting at CPC's national scale may remain slow, there are potentially opportunities for improving skill at a regional scale.

Through a series of prior annual workshops on climate variability, climate extremes, and drought held by the Council and the California Department of Water Resources (CDWR), some possible opportunities for improving forecasting skill at a regional scale have been identified. The purpose of this May 2015 workshop was to develop a Western vision for improving monthly and seasonal precipitation forecasting, loosely modeled after the Council's vision for an observing network for Western extreme precipitation. The analyses performed to understand patterns responsible for heavy precipitation events at a regional scale – such as atmospheric river storms or the Southwest monsoon -- also point out pathways to explore for improving forecasting of these events.

The timing is ripe for efforts to improve monthly and seasonal forecasting. Drought in the West has called attention to the need for better information to support preparedness and response, and NOAA's report on the California drought provides a focal point for follow-up actions. The National Weather Service (NWS) is reviewing approaches for developing experimental week three and week four outlooks. The National Research Council has convened a committee to develop a U.S. research agenda to advance sub-seasonal to seasonal forecasting.

NOAA image from GOES-West weather satellite. Although the accuracy of weather forecasts has improved considerably over a time span of decades, skill in seasonal forecasting remains a challenge.

WORKSHOP PRESENTATIONS

The workshop agenda and participant list are provided in the Appendix.

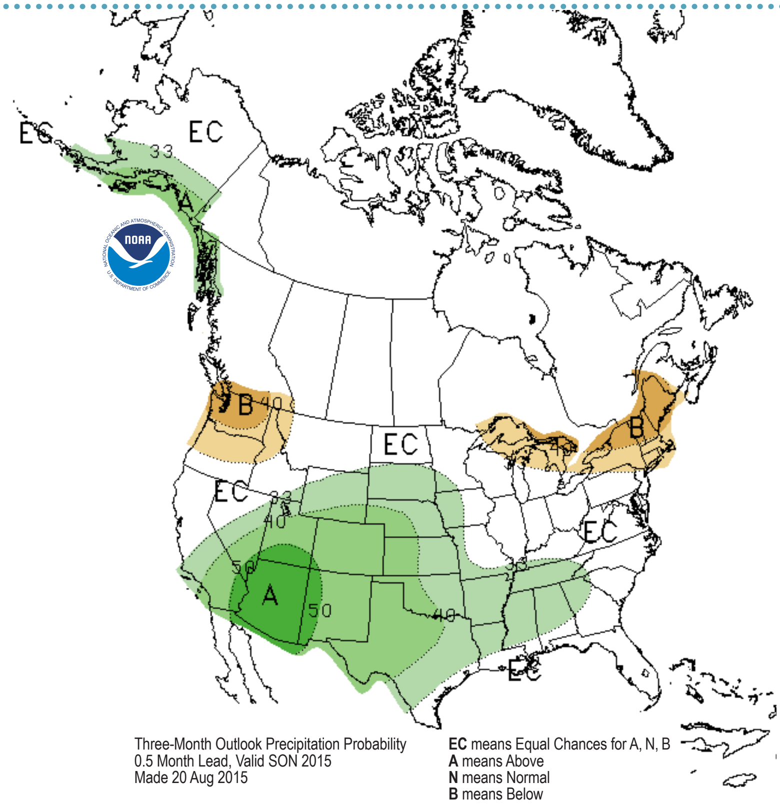
The meeting opened with remarks by Tony Willardson of the Council and Jeanine Jones of CDWR regarding the purpose of the workshop and its intended outcomes. The Council supports improving monthly and seasonal precipitation forecasting (see Appendix for copy of position statement), and also the weather and climate data collection networks needed to enable forecasting. Managing drought is a common challenge across the West, and one that would benefit from improved precipitation forecasting and data collection infrastructure. The Council is supportive of NOAA activities in this regard, and looks forward to identifying potential joint activities with NOAA organizations including the NWS (Western Region headquarters, CPC, and River Forecast Centers), the Office of Atmospheric Research (research labs and Climate Program Office), and the National Environmental Satellite, Data, and Information Service's (NESDIS's) National Centers for Environmental Information.

Going forward, CDWR has funded the Council to organize a series of four workshops to explore in more detail ways to advance progress on improving monthly to seasonal forecasting. The first workshop will be held in the fall in Salt Lake City, in collaboration with the NWS Western Region headquarters and NESDIS.

Presentations from NOAA speakers

Kevin Werner, NOAA's Western Regional Climate Services Director, discussed NOAA's service assessment for California's drought in 2014 (http://www.nws.noaa.gov/om/assessments/pdfs/drought_ca14.pdf). NOAA prepares service assessments to review its forecasting and warning services following major events; this report was NOAA's first assessment for drought. Assessments identify recommendations for improving service in future events, and the recommendations are tracked. The top request made by stakeholders interviewed was the forecast for the upcoming winter's precipitation; improving cool season precipitation forecasts for mountain watersheds was identified as a major opportunity. Stakeholders generally do not use CPC seasonal outlooks for decision-making as the skill of the forecasts is minimal and their scale is often not at the watershed level important for water resources. The capacity of stakeholders in different sectors to utilize NOAA information products varies; resource managers desire more in-depth technical products than the general public or emergency managers.

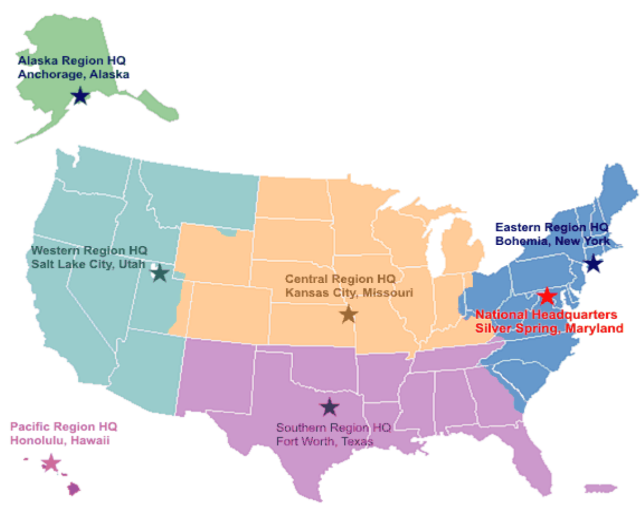
Jon Gottschalck, Chief of CPC's Operational Prediction Branch, described CPC's monthly and seasonal precipitation outlooks and the data and modeling behind them. He pointed out that although potentially useful detail (e.g., probability distributions) behind CPC's seasonal outlook products is available on the website, many viewers only look at the summary maps and may not be aware that more information is available. The skill (Heidke skill score) of the monthly and seasonal outlooks over the past decade has been very low, just marginally beating a random forecast. Dynamical models (specifically the NWS Climate Forecast System) and multi model ensembles (North American Multi-Model Ensemble) are the primary tools used to develop the outlooks; although still used, older statistical forecast tools (canonical correlation analysis and constructed analog tools) have not been an emphasis for continued development in recent years. It may be worthwhile to update the data sets for the older statistical tools, or to use statistical post-processing of dynamical model data, to improve precipitation forecasts. Work with statistical approaches is limited by availability of resources; CPC resources are first prioritized to dynamical modeling. CPC's five-year strategic plan has a goal of developing official week three and week four operational outlooks; these outlooks will need to capitalize on forecasts of opportunity, such as Madden-Julian Oscillation (MJO) activity. Initial work is beginning in the 2015 fiscal year. In the follow-up discussions to this presentation the point was made that improving precipitation forecasting in the dynamical models will be a long-term challenge; one area of improvement is better assimilation of ocean data. The need for reliable funding for ocean observations (e.g. continuity of the data provided by the Tropical Atmosphere Ocean program buoy array) to support the modeling was pointed out.



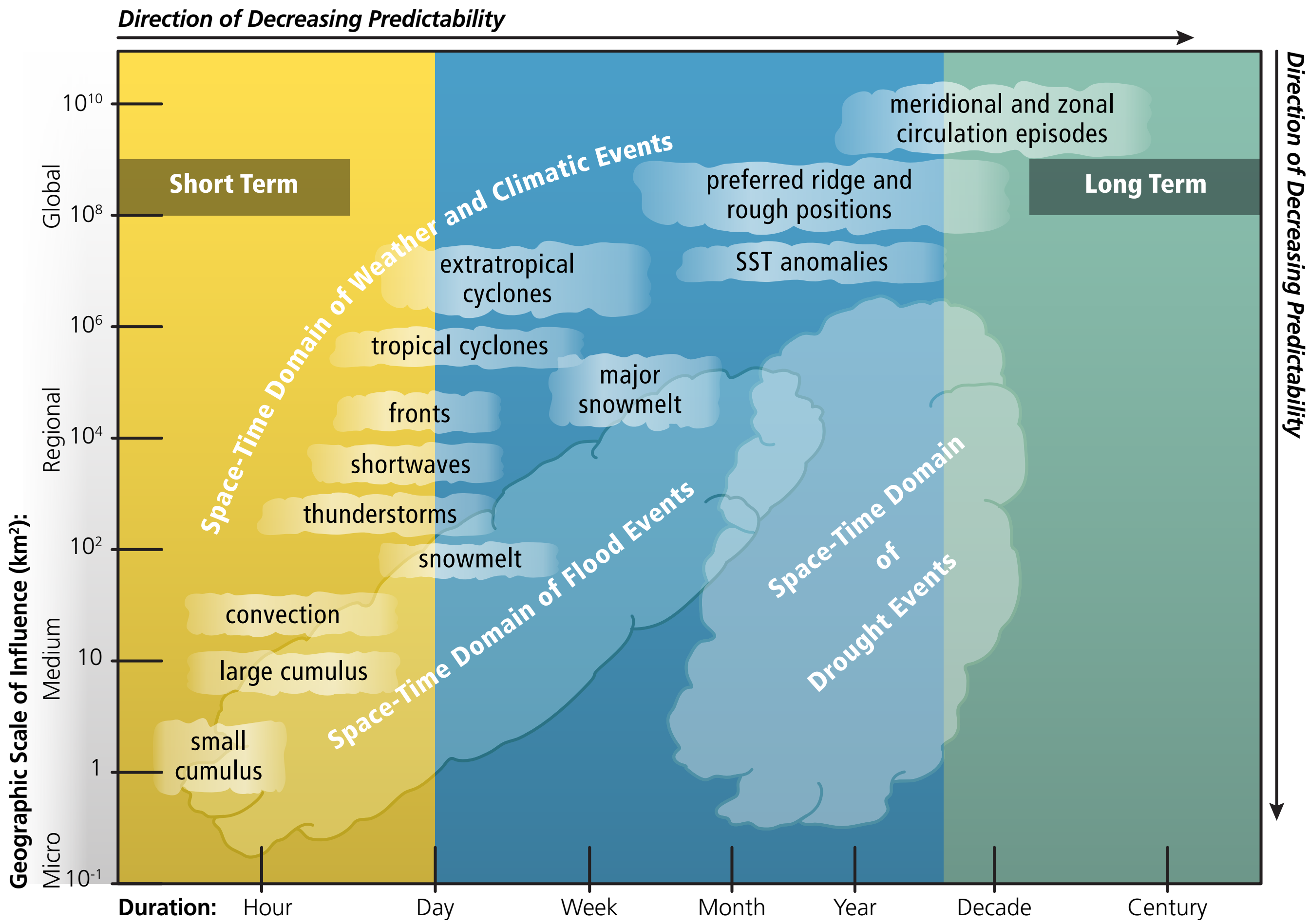
Example of a CPC precipitation outlook

NOAA research programs in the Office of Oceanic and Atmospheric Research were represented by "Ram" Ramaswamy, Director of the Geophysical Fluid Dynamics Laboratory (GFDL), and by Dan Barrie, Program Manager of the Modeling, Analysis, Predictions, and Projections (MAPP) program in the Climate Programs Office. Ram described GFDL's modeling work, emphasizing the need for seamless modeling across the weather to climate time continuum. He also covered the trade-off between modeling costs and higher-resolution modeling, and discussed development of the North American Multi-Model Ensemble, pointing out that inclusion of ocean data was important at the scale of seasonal forecasting. Dan described the MAPP program and the research it funds; the program's annual budget is about $12 million annually, about half of which is external grants. Subject areas covered in program include climate prediction from week two to inter-annual, drought research, and long-term climate outlooks.

Grant Cooper (Director of the NWS Western Region), Rob Hartman (Hydrologist in Charge of the California-Nevada River Forecast Center), John Lhotak (Development and Operations Hydrologist of the Colorado Basin River Forecast Center), and Roger Pierce (Meteorologist in Charge of the San Diego Weather Forecast Office) discussed NWS forecast services and activities at the regional and local scale and the process of making streamflow and weather forecasts for stakeholders. NWS has a five year strategic plan; its annual budget priorities for forecasting operations are developed at these local and regional levels and passed on up to headquarters. The NWS Western Region includes three river forecast centers, 24 weather forecast offices, and four aviation forecast units. Hydroclimate characteristics of the region include extensive areas of snowmelt-dominated hydrology and high climate variability, with sophisticated water stakeholders who place a priority on improving forecasting beyond the weather timescale. Challenges in the West include making observations (e.g. mountain precipitation, radar coverage), maintaining funding for observing systems, and predicting extremes. Challenges of incorporating new technology include developing track records to support the transition from research to operations, such as a 25-year climatology of atmospheric river storms.



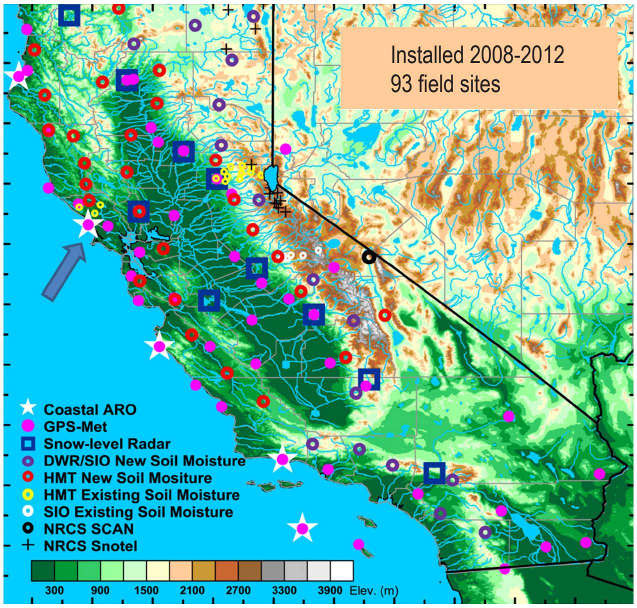
NWS Regions



Relationship of event scale and duration to predictability, from the federal Climate Change and Water Working Group

Perspectives from state climatologists and climate programs

Mike Anderson (State Climatologist, CDWR), Kathie Dello (Associate Director, Climate Change Research Institute, Oregon State University), and David DuBois (State Climatologist, New Mexico State University) gave their perspectives on data and forecasts. The saying that all models are wrong but some are useful was noted, as was the fact that information users do not trust seasonal forecasts made with currently available processes. (It was also pointed out that the concept of forecast skill can have vastly different meanings for forecasting meteorologists than it does for water managers, and that this subject needs to be better explored.) Understanding processes/events that are regionally important contributors to seasonal precipitation offers promise – e.g. atmospheric river storms for California and the Pacific Northwest, the monsoon for the Southwest (North American Monsoon Experiment). David noted that the monsoon amounts on average to about half of New Mexico's average annual precipitation, and that the dew point is used to provide near-term forecasting support for monsoon onset. The 2015 monsoon season has been used as an example of how monsoon precipitation could affect water management decisions – the U.S. Bureau of Reclamation's 24-month modeling study for operation of Lake Powell and Lake Mead suggested that a 2016 shortage would be triggered for the Lower Colorado River Basin states, but a subsequent active summer monsoon season (together with moisture from tropical cyclones) raised the elevation of Lake Mead sufficiently to avoid the shortage trigger, which is determined



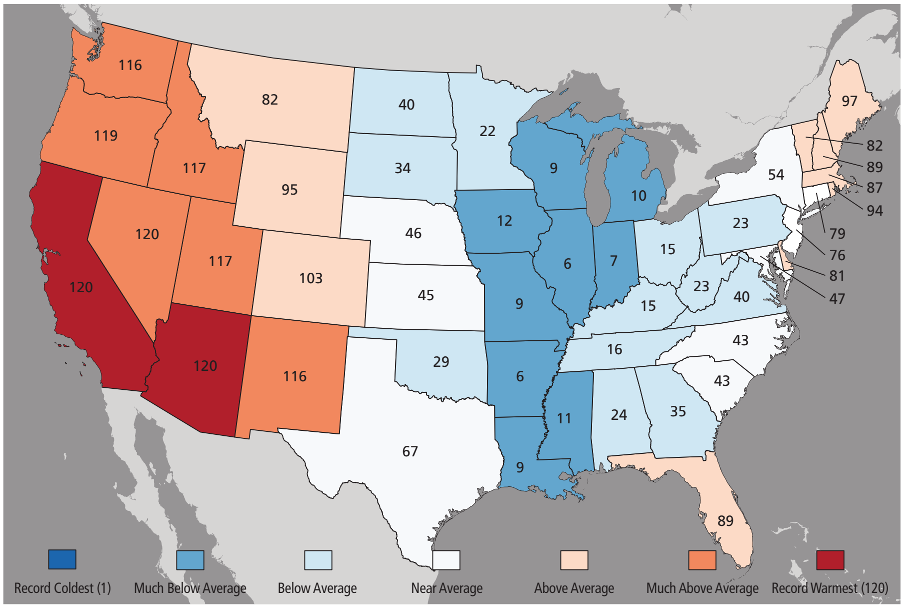
based on the August model study. Forecasting drivers of these important precipitation sources, as opposed to forecasting the precipitation itself, was suggested as a potential approach for improving prediction skill. Utilization of the MJO signal, when present, is another potential tool. These approaches could be addressed through a blending of dynamical and statistical modeling efforts. Additionally, implications of record warm temperatures across much of the West need to be considered (the “snow drought” of water year 2015) in the context of using historical observations. It was pointed out that over the long-term climate change will be “stacking the deck” with more low snowpack years, which impairs the performance of existing water infrastructure designed largely on the basis of pre-1950s hydrologic conditions.

Presentations from research community

Soroosh Sorooshian (University of California (UC) Irvine), Amir AghaKouchak (UC Irvine), and Ali Behrangi (National Aeronautics and Space Administration, Jet Propulsion Laboratory) described research projects representing examples of actions that could support improving seasonal forecasting. Soroosh, together with his team members Phu Nguyen and Hao Liu, covered building on the PERSIANN climate data record of remotely sensed precipitation, using object-oriented data analysis to develop a catalog of historical atmospheric river storms. Reconstructing the large historical precipitation events is a first step toward statistical analysis of conditions favoring or blocking formation of atmospheric river storms which could assist with prediction. Amir’s presentation covered development of an analog years database matching California precipitation (by climate division) with conditions such as ENSO or the Pacific Decadal Oscillation, and use of remote sensing information to condition the purely statistical analog years model to produce seasonal forecasts. The analog years database is being installed on a CDWR server for CDWR’s staff to use in performing scenario analysis of water year types. Ali discussed initial work with another statistical modeling approach using temperature, precipitation, and ENSO observations to forecast the standardized precipitation index (for drought prediction purposes) at a national scale. This effort builds on other NASA work done for a NASA/U.S. Agency for Internal Development regional data visualization and monitoring system.

Perspectives from water agencies on forecasting needs & potential applications

Representatives from ten state and local water agencies shared their perspectives on seasonal forecasting needs and applications. Responsibilities



(Left to Right)

A $25 million observing network was installed in California with funding from NOAA's Hydromet Testbed program and CDWR.

The North American Monsoon Experiment has improved understanding of the Southwest monsoon, which provides much of the annual precipitation for Arizona and New Mexico.

Record temperatures were observed across the West in 2014. (NOAA figure)

of these agencies range from operation of large water infrastructure projects to regulation of water rights or administration of water agreements. The agencies' focus is largely on decision-making at timescales of multiple weeks to a season, primarily for water supply management, rather than short-term decision-making for flood control purposes (which is comparatively well supported by existing weather forecasting capability). Many of the agencies share a common setting of snowpack-influenced or snowpack-dominated hydrology, and all expressed an interest in using seasonal precipitation forecasts with greater skill and reliability than those currently available. Although the specific timing of when sub-seasonal precipitation forecasts were desired varied with the climatologies of the watersheds and decision calendars of individual agencies, there was common interest in improved fall seasonal precipitation forecasts at different lead times for the winter period.

For agencies owning and operating large water infrastructure, one use of better seasonal forecasts would be to help plan reservoir operational scenarios or to make preliminary estimates of water allocations to users. Other decisions that could be supported by seasonal forecasts include budget planning (e.g., the need to increase water conservation budgets if drought conditions are expected), negotiating and permitting water transfer agreements, or implementing shortage contingency measures. At the local agency

"Many of the agencies share a common setting of snowpack-influenced or snowpack-dominated hydrology, and all expressed an interest in using seasonal precipitation forecasts with greater skill and reliability than those currently available."

or water retailer level, seasonal forecasts may be used to estimate the supplies likely to be available from a water wholesaler. Having longer lead times for making decisions about managing for shortages – which often requires balancing competing interest or seeking supplemental resources – is very valuable.

"Water agencies stressed the need for skillful/reliable precipitation forecasts, and pointed out the potentially large adverse consequences of acting on an incorrect forecast."

Water agencies stressed the need for skillful/reliable precipitation forecasts, and pointed out the potentially large adverse consequences of acting on an incorrect forecast. The challenges of financing new water infrastructure and the increasing competition for existing water supplies lead to opportunities to improve water management efficiency that could be aided by improved forecasting. There is need for better collaboration and communication between forecasters and water managers, which might also help with the distrust of existing seasonal climate outlooks within the water user community (during the discussions several participants noted that the Old Farmers' Almanac has more credibility with their water users than do federal agency science products). Better mutual understanding of user requirements and climate processes and forecasting tools should lead to more nuanced application of whatever information is available.

Water users in the Upper Colorado River Basin are exploring extraordinary drought operations scenarios for USBR's Lake Powell.

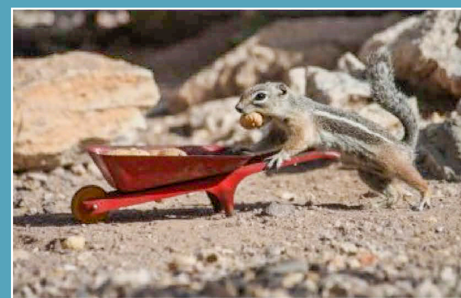
Some specific points about forecasting applications made in the agencies' presentations include:

- Runoff in the Colorado River Basin is strongly dominated by high-elevation snowpack conditions – about 15 percent of the watershed area produces 85 percent of the runoff. The basin is unique for its substantial storage capacity, roughly 60 million acre-feet (MAF) or four times the average annual inflow to Lake Powell. Historically this storage limited the need for seasonal forecasts by agencies holding U.S. Bureau of Reclamation (USBR) water supply contracts, although some water users had expressed interest in two-year forecasts for the upper watershed to match the 24-month modeling studies USBR runs for its reservoir operations planning. This situation is now changing due to the 15-year drought in the basin and declining reservoir elevations in Lake Mead and Lake Powell that could trigger shortage management actions. The Lower Basin States are becoming increasingly interested in single-year forecasts as Lake Mead levels near the elevation that would trigger a first-ever federal shortage declaration in the Lower Basin. Under the current federal reservoir operating criteria, USBR's August 24-month modeling study is used to determine if shortage conditions would be declared beginning in January for the following year. Federal contractors having to reduce their use of river water would have those intervening months to put in place measures to reduce use. Skillful seasonal forecasts would be helpful in providing greater lead-time to implement such actions when needed, and also for providing guidance to support other activities by Lower Basin water users who are taking extraordinary conservation measures to retain more water in Lake Mead to avoid hitting a shortage elevation trigger. As was demonstrated in the 2015 monsoon season, a summer lower watershed (monsoon) forecast could also have value for Lower Basin water contractors making plans for cutbacks if shortage conditions were declared. In the Upper Basin, water users are evaluating potential new operating criteria (for drought contingency planning) for the smaller reservoirs above Lake Powell (the largest of which is the 3.8 MAF Flaming Gorge Reservoir). There is interest in developing ability to take actions beyond the normal operations to avoid hitting emergency action triggers for maintaining a minimum power generation elevation at Lake Powell. Although actions to temporarily conserve water in Powell or to move water down from the upstream reservoirs could avoid hitting a trigger, they would come at a significant water cost to Upper Basin users if the forecasts were wrong – emphasizing the importance of accurate forecasts.

- The Salt River Project (SRP) in Arizona operates six reservoirs with a total conservation storage of 2.3 million acre-feet (MAF) and approximately 267 groundwater wells, to supply a service area of almost 400 square miles in the greater Phoenix metropolitan area. SRP uses a philosophy of maintaining reservoir carry-over storage to manage the worst drought on record, to reduce the probability to less than one percent of having to cut its water allocation to two acre-feet per acre. If the risk appears likely to be greater than one percent, supplemental supplies will be identified. SRP includes paleodroughts in its analysis of historical droughts. Sub-seasonal forecasting capabilities represent its major gap in information availability – such as tools that might use trends to narrow the range of forecast possibilities, identify important forecast skill thresholds, or identify major changes in the state of the climate. Precipitation

Weather Forecast "Tools"

Winter Outlook 2014-2015



NATURE — Wet Winter

- Lots of acorns
- Pine cones gathered on the top of the tree
- Frequent rings around the sun
- Large spider webs
- Woolly worms with thin brown stripe

Average

Mild

Severe

- Bees become secluded
- Woodpeckers sharing trees
- Raccoons with thick tails
- Mice overeating
- Wildlife putting on early and thick winter coats
- Squirrels gathering nuts
- Spleen of big game animals

A water manager's perspective on other tools for seasonal forecasting.

The SWP's California Aqueduct is the only conveyance facility that moves water from the Central Valley to Southern California.

guidance products might be categorical outlooks similar to CPC seasonal outlooks or extended quantitative precipitation forecasts. The status of ENSO conditions alone provides limited predictive information – historically the best signal has been that a strong La Nĩna is associated with a dry winter.

- CDWR owns and operates the State Water Project (SWP), California's second-largest water project and largest urban water supply project. Project facilities include 20 dams, 662 miles of aqueduct, and 26 power and pumping plants; twenty-nine local agencies hold contracts with CDWR for 4 MAF of project water. SWP operations in the Sacramento-San Joaquin River Delta are very closely coordinated with those of USBR's Central Valley Project, as both projects divert water from the Delta and jointly meet water quality and Endangered Species Act regulatory requirements there. CDWR also manages a regional flood control project and has other flood control responsibilities, manages hydrologic data collection programs including the California Cooperative Snow Surveys program, and provides operational snowmelt runoff forecasts statewide; its flood management program has for many decades been co-located and closely integrated with the NWS California-Nevada River Forecast Center. From the perspective of statewide water management, and especially for drought preparedness and response, CDWR's priorities for skillful seasonal and sub-seasonal precipitation forecasting are a winter season forecast available by the latter part of November, and a mid-winter forecast available in mid-January. These timeframes reflect the fact three-fourths of California's statewide precipitation occurs from November through March, with half occurring from December through February. The bulk of California's water budget comes from a small number of storms (typically less than ten annually); the ability to improve predicting conditions favorable for big events is key to improving seasonal forecasting.

- CDWR's responsibilities for flood control date back to the 1911 formation of the State Reclamation Board and the 1917 authorization of the Sacramento River Flood Control Project, initially focusing on the extensive system of levees protecting lives and property in the Central Valley. Major reservoirs were constructed by federal and local agencies and by CDWR on Sierra Nevada rivers tributary the valley (the rivers providing much of the state's developed water supplies as well as posing the greatest flood risks) beginning in the early part of the 20th century. USACE flood control rule curves govern winter season operation of these major rim reservoirs; the hydrologic records available for developing the curves were largely from the first half of the 20th century. Given needs to improve downstream flood risk reduction and to manage increased competition for water supplies, CDWR has been undertaking efforts to improve the efficiency of reservoir operations through use of technologies not available when the reservoirs were constructed. The first effort, forecast-coordinated operations, is intended to improve downstream flood protection by using new data sources (new NOAA-CDWR observing system for extreme precipitation), the substantial improvements in short-term weather forecasting that have occurred since the 1950s, and improvements in runoff modeling to produce flood forecasts that optimize timing of flood control releases. A pilot project has been underway with CDWR's 3.5 MAF Lake Oroville and Yuba County Water Agency's 1 MAF New Bullards Bar Reservoir, in partnership with USACE and NWS, with a subsequent similar project then following for San Joaquin River Basin reservoirs. Forecast-informed operations is a second effort that in addition to reducing flood risk could provide water supply enhancement; this effort is in the exploratory planning stages. In concept, improved seasonal reservoir inflow forecasts would be paired with (new) dynamic flood control rule curves and use of ensemble runoff event forecasts to optimize use of reservoir storage capacity. Actual implementation of this concept would have to occur via willing partnerships with owners of individual reservoirs; changes to existing USACE rule curves would require an environmental review process and likely congressional authorization. Over the long-term, the ability to incorporate additional hydrologic data and changed climate conditions into winter operation of existing reservoirs is very important for climate change adaptation; climate models suggest that end of century Sierra Nevada snowpack could be only 20 percent of historical levels.

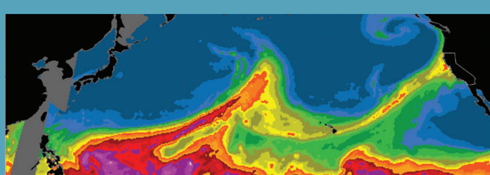
- In the Missouri River Basin, the Montana Department of Natural Resources and Conservation (DNRC) owns Tongue River Dam, used primarily for agricultural water supply, and operated by the Tongue River Water Users Association. The dam's inlet tower freezes by December, and there is then no ability to operate the 150 thousand acre-foot (TAF) reservoir (for short-term flood control needs during the winter) except in a spill mode until the spring thaw. The DNRC would like better forecast guidance to help with the decision of where to set the reservoir elevation/ice layer in November, to avoid over-spilling the reservoir and maximize water supply availability for the irrigation season.

- The U.S. Army Corps of Engineers (USACE) owns the six major reservoirs on the Missouri River mainstem, including the 19 MAF Fort Peck Lake in Montana. Following the river basin's record 2011 flooding, there was a formal USACE review of how the reservoirs were operated to manage the flooding. One finding of the review was that the record precipitation in the watershed could not have been predicted with available forecasting methods, but that USACE's annual operating plan should have recognized the fact that a greater number of extreme events has been occurring in the recent part of the hydrologic record. Montana is interested in exploring seasonal forecasting that could potentially support better balancing between retaining water in storage and making seasonal flood control releases.

- In California's Russian River Basin, Sonoma County Water Agency (SCWA) contracts with USACE for water supply from USACE's 122 TAF Lake Mendocino. The reservoir, originally constructed primarily for flood control purposes, receives about half of its inflow from atmospheric river storms, and these storms account for more than 80 percent of the variance in total precipitation. Historically the watershed has had relatively high vulnerability to both drought and flood impacts, with increasing water demands over time for permanent crops, urban supplies, and three ESA-listed salmonid species. SCWA is pursuing several approaches to improve water supply reliability, one of which is exploring use of forecast-informed reservoir operations to improve the reservoir's operational efficiency. SCWA is working on a demonstration project with USACE, USBR, NOAA, CDWR, and the U.S. Geological Survey. The intent of the project in the near-term is to incorporate current weather forecasting skill into reservoir operations, especially when no storm events are predicted and forecast skill is generally higher, and in the longer-term to develop the capability to predict landfall and intensity of atmospheric river storms to inform reservoir operations. Challenges involved include reaching agreement on how to operationalize research products and new technology into reservoir operations. It is recognized that this will be a long-term effort, but SCWA hopes to be able to begin making short-term initial improvements in operations.

Atmospheric Rivers and California

NOAA's Hydrometeorology Testbed program and CDWR cost-shared in the research and installation of a $25 million observing system for extreme precipitation, focused on atmospheric river storms. The project led to the realization that these storms are major contributors to California's average annual water supply as well as being responsible for most episodes of large-scale flooding. Conversely, since California's annual precipitation is dependent on a small number of winter storms and the presence or absence of a few significant storms determines whether the water year will be wet or dry, the ability to predict absence of atmospheric river storms may be the key to seasonal drought prediction. CDWR has funded research to develop historical databases of these storms from climate model reanalysis data, as a step to examining predictive capability for them.



Satellite image of atmospheric river reaching West Coast. Atmospheric river storms – storms fueled by concentrated streams of water vapor from the Pacific Ocean – are big contributors to annual water supply conditions. A few major storms more or less shift the balance between a wet year and a dry one. (Image courtesy NOAA Hydrometeorology Testbed.)

Action items & closing remarks

There was consensus that near-term opportunities for improving seasonal/sub-seasonal forecasting opportunities at a Western scale center around opportunities to improve forecasting of events that are large contributors to annual precipitation (e.g., atmospheric river storms or the Southwest monsoon), and to selective updating of statistical analytical tools and models. Conceptually this could entail, for example, developing experimental forecasts of atmospheric river storms with the ultimate goal of operationalizing these forecasts into NWS products such as the CPC outlooks or into a more specialized forecast product for water management at a river basin spatial scale. NOAA's ten-year hurricane forecast improvement project could be a potential model for this effort.

There was also agreement that a process of ongoing coordination between NOAA and water agencies on sub-seasonal/forecasting is needed. It was suggested that regular meetings be set up between NOAA's forecasters and modelers and water agency users of these products. One topic to be covered in these meetings would be developing additional clarification/explanation of information available for CPC's existing precipitation outlooks, such as skill scores and forecast statistics, to make this material more accessible for water agencies.

The Council wants to work with NOAA to better understand the resources required for improving sub-seasonal/seasonal forecasting and how the Council can assist. The Council could facilitate the involvement of water sector stakeholders such as the Association of California Water Agencies or of projects such as the Western Governors' Association drought initiative.

The workshop's specific follow-up actions are:

- preparing a workshop report
- organizing a joint Council/NOAA October meeting at the NWS regional headquarters in Salt Lake City to identify specific research needs and operational strategies for advancing sub-seasonal/seasonal precipitation forecasting. These needs and strategies are expected to form the basis for initiatives by NOAA and/or by the Council to advance the state of science and practice for seasonal prediction for water resources.
- additionally, the Council will be holding further meetings on this subject with water users at the December Colorado River Water Users Association meeting and with NOAA headquarters in Washington DC in early 2016.

APPENDIX

Workshop Agenda

Participant List

WSWC Position #366

WORKSHOP AGENDA

Improving Sub-Seasonal and Seasonal Precipitation Forecasting for Drought Preparedness

Doubletree San Diego Downtown
May 27 – 29, 2015

Wednesday May 27

11:00 Registration

1:00 Welcome and Opening Remarks, Workshop Background and Desired Outcomes

Tony Willardson, Executive Director, Western States Water Council (WSWC)

Jeanine Jones, Interstate Resources Manager, California Department of Water Resources (CDWR)

1:30 NOAA Services Assessment for California Drought – Kevin Werner, Western Regional Climate Services Director, NOAA NCEI

2:15 NOAA's NWS Climate Prediction Center (CPC) Activities, Jon Gottschalck, Chief, Operational Prediction Branch, CPC

3:00 Break

3:15 NOAA's NWS Western Region Activities – Grant Cooper, Director, Western Region NWS

3:45 Forecasting Needs of NWS River Forecast Centers (RFCs) and Weather Forecast Offices (WFOs)

California-Nevada RFC, Rob Hartman, Hydrologist in Charge

Colorado Basin RFC, John Lhotak, Development & Operations Hydrologist

San Diego WFO, Roger Pierce, Meteorologist in Charge

5:15 Adjourn

6:00 Reception

Thursday May 28

7:30 Continental Breakfast

8:30 NOAA's Research Program

Geophysical Fluid Dynamics Laboratory, V. "Ram" Ramaswamy, Director

9:00 Regional-Scale Research Projects

Building an Atmospheric Rivers Catalog using a big data approach, Soroosh Sorooshian, Distinguished Professor, UC Irvine

Conditioning an analog years database, Amir AghaKouchak, Assistant Professor, UC Irvine

Using temperature and humidity observations for advancing prediction, Ali Behrangi, Scientist, NASA JPL

10:30 Break

10:45 Western State Climatologists Perspectives on Precipitation Forecasting

Mike Anderson, State Climatologist, CDWR

Kathie Dello, Associate Director, Climate Change Research Institute, Oregon State University

David DuBois, State Climatologist, New Mexico State University

12:15 Lunch (on your own)

1:45 NOAA's Research Programs

Modeling, Analysis, Predictions, and Projections program, Dan Barrie, Program Manager, NOAA's Climate Program Office

2:15 Forecasting Needs and Water Agency Perspectives – Drought Preparedness and Response

Robert Mace, Deputy Executive Administrator, Texas Water Development Board

J.D. Strong, Executive Director, Oklahoma Water Resources Board

Jeanine Jones, Interstate Resources Manager, CDWR

3:45 Break

John Longworth, Statewide Projects Manager, New Mexico Office of the State Engineer

4:00 *James Rufo-Hill, Climate Resilience Advisor, Seattle Public Utilities*

Charlie Ester III, Manager, Water Resources Operations, Salt River Project

5:30 Adjourn

Friday May 29

7:30 Continental Breakfast

8:30 Forecasting Needs and Water Agency Perspectives (continued)

Eric Kuhn, Secretary/General Manager, Colorado River Water Conservation District

9:30 Break

9:45 Potential Applications – Reservoir Operations

Missouri River System, Tim Davis, Administrator, Montana Department of Natural Resources

Upper Colorado River Basin reservoirs, Don Ostler, Executive Director, Colorado River Compact Commission

Forecast Informed Reservoir Operations (FIRO) in Russian River System, Jay Jasperse, Chief Engineer/Director of Groundwater Management, Sonoma County Water Agency

FIRO for Central Valley Reservoirs, Boone Lek, Senior Water Resources Engineer, CDWR

11:45 Action Items and Closing Remarks

12:15 Adjourn

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Sub-Seasonal and Seasonal Precipitation Forecasting Workshop

Doubletree San Diego Downtown
May 27 – 29, 2015

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WSWC POSITION #366

Resolution of the Western States Water Council Supporting Federal Research and Development of Updated Hydroclimate Guidance for Floods & Droughts

Helena, Montana
July 18, 2014

WHEREAS, Western states continue to experience extreme flooding, droughts, or wildfires that threaten public safety, tax aging water infrastructure, and/or have significant economic consequences; and

WHEREAS, according to the National Oceanic and Atmospheric Administration (NOAA), the nation's top ten multi-billion dollar disasters have occurred since 1980, with six of those in the last decade; and

WHEREAS, we must be prepared to effectively manage for frequent, extensive, and severe storms, floods, coastal inundation, and droughts; and

WHEREAS, Western states experienced extreme drought in 2011-2014, as well as recent floods of record in areas such as parts of the Missouri River Basin in 2011 and Colorado in 2013, and further Winter Storm Atlas in 2013; and

WHEREAS, key long-term observation networks needed for monitoring extreme events, such as USGS streamgages and the NWS Cooperative Observer network, face continued funding and programmatic challenges that threaten the continuity of crucial long-term data records; and

WHEREAS, snow water content and soil moisture monitoring are also critical for drought and flood forecasting and management, but the NRCS snow survey and water supply forecasting program, related SNOTEL sites, and its Soil Climate Analysis Network remain underfunded; and

WHEREAS, some of NOAA's probable maximum precipitation estimates used by water agencies for dam safety and other analyses have not been updated since the 1960s and the federal Guidelines for Determining Flood Flow Frequency Analysis (published as Bulletin 17B) have not been revised since 1981; and

WHEREAS, flood frequency analyses are used by public agencies at all levels of government to design and manage floodplains, and for construction of flood control and stormwater infrastructure, with Bulletin 17B still representing a default standard of engineering practice; and

WHEREAS, federal funding for hydrology research has waned since the 1970s-1980s, and alternative statistical methodologies for flood frequency analyses or deterministic analytical procedures are not being supported and transitioned to common engineering practice; and

WHEREAS, the Federal Emergency Management Agency has adopted a process for local communities to explicitly incorporate "future conditions hydrology" in the national flood insurance program's flood hazards mapping; and

WHEREAS, the present scientific capability for forecasting beyond the weather time domain – beyond the ten day time horizon – and at the subseasonal to interannual timescales important for water management is not skillful enough to support water management decision-making; and

WHEREAS, the Council has co-sponsored a number of workshops on hydroclimate data and extreme events, to identify actions that can be taken at planning to operational time scales to improve readiness for extreme events; and

WHEREAS, multiple approaches have been identified at these workshops that could be employed at the planning time scale, including ensembles of global circulation models, paleoclimate analyses, and improved statistical modeling, that could be used to improve flood frequency analysis or seasonal forecasting; and

WHEREAS, advances in weather forecasting research, such as that of NOAA's Hydrometeorological Testbed program on West Coast atmospheric rivers, demonstrate the potential for improving extreme event forecasting at the operational time scale; and

WHEREAS, WGA and NOAA signed a Memorandum of Agreement in June 2014 on improving resilience to droughts and floods;

NOW, THEREFORE, BE IT RESOLVED, that the federal government should update and revise its guidance documents for hydrologic data and methodologies – among them precipitation-frequency estimates, flood frequency analyses, and probable maximum precipitation – to include subsequently observed data and new analytical approaches.

BE IT FURTHER RESOLVED, that the federal government should place a priority on improving subseasonal and seasonal precipitation forecasting capability that would support water management decisions.

BE IT FURTHER RESOLVED, that the Western States Water Council supports development of an improved observing system for Western extreme precipitation events such as atmospheric river storms, as well as baseline and enhanced stream, snow and soil moisture monitoring capabilities.

BE IT FURTHER RESOLVED, that the federal government should sustain and expand its Hydrometeorology Testbed – West program, in partnership with states and regional centers, to build upon the initial progress made in that program for developing and installing new technologies for precipitation observations.

BE IT FURTHER RESOLVED, that the Western States Water Council urges the federal government to support and place a priority on research related to extreme events, including research on better understanding of hydroclimate processes, paleoflood analysis, design of monitoring networks, and probabilistic outlooks of climate extremes.

BE IT FURTHER RESOLVED, that the Western States Water Council will work with NOAA and WGA in supporting efforts on climate extremes, variability, and future trends.