5A.4

NATIONAL WATER RESOURCES MONITOR and OUTLOOK: A NEW NATIONAL SCALE PRODUCT for TIMELY WATER INTELLIGENCE

Andrea J. Ray[1], Michelle Stokes[2], Heather Yocum[3], Ashley Nielson[2], Cass Goodman[2], Robert K. Hartman[4], J. A. Intermill III[5], Michael. C. Kruk[6], Russell Vose[6], David Miskus[7]

[1] NOAA Earth Systems Research Laboratory Physical Sciences Division (ESRL/PSD), Boulder, CO;[2] NOAA/NWS Colorado Basin River Forecast Center (RFC), Salt Lake City, UT; [3] Univ. of Colorado Cooperative Institute for Research in Environmental Sciences at the NOAA/ESRL/PSD, Boulder, CO; [4]NOAA/NWS California-Nevada RFC, Sacramento, CA (now Hartman Consulting Services); [5]NOAA/NWS Northwest RFC, Portland, OR; [6]NOAA/NESDIS National Centers for Environmental Information, Ashville, NC; [6]NOAA/NWS Climate Prediction Center

1. INTRODUCTION

A new online tool, the Water Resources Monitor and Outlook (WRMO), is being designed and developed by a cross-line office team at National Oceanic and Atmospheric Administration (NOAA) in partnership with the National Integrated Drought Information System (NIDIS) the National Weather Service (NWS) Western River Forecast Centers (RFCs) and the Climate Prediction Center (CPC), the NESDIS National Centers for Environmental Information (NCEI), and NOAA's Physical Sciences Division (PSD). This integrated product team is drawn from science and operational product expertise organizationally and geographically dispersed of across NOAA. This team, in concert with NIDIS, is developing a prototype water resources monitor and outlook application across western RFC domains that is intended for nationwide implementation. This tool will provide consistent access to RFC Ensemble Streamflow Prediction (ESP) water supply forecasts along with a suite of climate and hydrological information, visualization and analysis of observed and seasonal forecast data; forecast evolution; and verification tools to improve water resource information delivery to water management stakeholders.

The WRMO responds to requests from and documented needs of water managers for an integrated and synthesized tool for water resource-related data and predictive information. The WRMO will integrate hydrometeorologic monitoring, forecasts, and outlooks, and recent scientific advances in weather and climate prediction into the product suite. Ultimately the product suite will contain three web-based elements: 1) water resources monitoring information 2) water resources outlook that is an enhancement of the current product (both 1 and 2 updated daily) and 3) sub-seasonal to seasonal climate outlooks for water resources. The seasonal water outlooks will leverage the existing operational forecasts at CPC together with some forecast verification tools, and have the intent improve the usability of subseasonal to seasonal (S2S) forecast products that have been identified as a high priority by water supply management stakeholders, including the new NOAA CPC week 3-4 products.

The NWS River Forecast Centers have issued operational water supply forecasts and information for decades at lead times up to six months at hundreds of locations across the western United States. The strength of

*Corresponding author address: Andrea J. Ray, NOAA/ESRL/PSD, 325 Broadway, Boulder, C0 80205, andrea.ray@noaa.gov

these products is that they are generated from real-time hydrologic modeling systems that incorporate hydrometeorological data and the latest weather and climate forecasts. These water resources products are used every year to inform multi-million dollar water management decisions. However, these products have a variety of graphical and tabular display formats that are generally limited to their forecast basin boundaries (Figure 1) and presented in a fragmented and often inconsistent way. With growing demands on water supply, significant impacts of droughts, and growing importance of forecasts in the water management decision-making processes, a consistent centralized location to access all information related to water supply forecasts and information is long overdue.

Figure 1. NWS River Forecast Center domains.

2. IMPORTANCE OF WATER SUPPLY FORECASTING

Water supply is increasing in importance in the US, as population increases in water scarce areas, demand is growing due to environmental vulnerabilities, the need for power generation. In the West, as much as 75% of the region's water supply is derived from precipitation that is stored during the cool season in mountain snowfields, and then released in stream throughout the warm season (USGS 2005). Furthermore, climate change is likely to impacts supply, and there are competing demands for water among users. As a result, there is more and more scrutiny of management, and requests for more and more information regarding water supply forecasts.

Water supply outlooks are used for: reservoir operations; drought outlooks; to manage irrigation, which has implications for food production; to plan for power generation which influences the price of electricity; for flood control; to estimate water supply to communities; and for a number of environmental issues including habitat for endangered species and water quality. Major users of RFC water supply outlooks include federal, state, and quasi-governmental managers who manage risks for the public or provide information to others who do so.

3. WATER MANAGEMENT STAKEHOLDER NEEDS

Water resource institutions in the Western U.S. have an unmet need for integrated source for water resource–related data and predictive information that limits meeting drought risk management goals. Most recently, Western States Water Council position statement (WSWC 2014) and the Western Governors' Association MOU with NOAA illustrate that this requirement has grown in importance to the region's leadership and people. The 2014 NOAA Service Assessment for the California Drought (Werner et al 2015) describes a that institutions in the western US are often ready to use information but there are improvements needed in accessibility, relevance and understandability of the products in order to fully realize the value of NOAA's existing drought services.

There is a significant literature on information needs for water management in the western U.S, where we are prototyping the WRMO. While user needs are not synonymous with "readiness"—not all "needs" expressed imply readiness—they are a starting point indicating an institution is considering how to use the information, and likely has some level of readiness. In addition to the service assessment (Werner et al 2014), these studies include: an evaluation of the Upper Colorado River Basin (CRB) NIDIS

Early Warning System (EWS, McNie 2014); studies of drought metrics (Steinemann, 2015, 2014), studies focused on CRB managers (Ray and Webb 2015; Werner et al 2013; Dilling and Berggren 2012; Lowrey et al 2009; Ray 2004); and water managers in the west (Barsugli et al. 2012; McNie 2007; Ray and Webb 2015); studies of seasonal forecasts themselves (Dilling and Lemos 2011); and even findings of River Forecast Center stakeholder meetings (Werner, et al. 2010-2014; CNRFC (www.klamathdss.org/noaagrant.php).

Under NIDIS funding, we are collecting feedback to refine user needs specifically for this product, with specific stakeholders, including collecting feedback at NIDIS Drought Early Warning System (DEWS) meetings.

4. THE WRMO TOOL

There is a need for a national product for users who are interested in areas crossing RFC boundaries or a very high level view of how water availability varies across the country, and to provide improved visualization tools and verification information. The WRMO vision and goal is to provide a comprehensive view of the water resource conditions that will meet local, regional, and national interests, is a new prototype product designed to meet this need for centralized and consistent information across RFC boundaries. Additional goals of the WRMO are to provide better access to existing products that meet documented stakeholder needs, as well as facilitate better understanding of the products, and use in risk management and decisionmaking by water management stakeholders.

The product builds on existing but historically separated capabilities within NOAA, including regional RFC forecasts, weather prediction capabilities, NCEI data and analytical capabilities, as well as those of the new National Water Center. Roll-out of the prototype is anticipated in mid-FY'2017, with enhancements planned as funding permits. The prototype will be available at: http://CBRFC.noaa.gov/WRMO.

The web page for the product will open with a (Figure 2) clickable regional map with RFC forecast points indicated, color-coded for water supply status. By clicking on a point, By clicking on the point, a user will be able to includes graphics (maps and plots) which can be generated on the fly, specified through the selection of available user options. For example, for any forecast point, users will be able to generate a Forecast Ensemble (Figure 3) and bar graphs depicting the Probabilistic Water Supply Forecast (Figure 4).

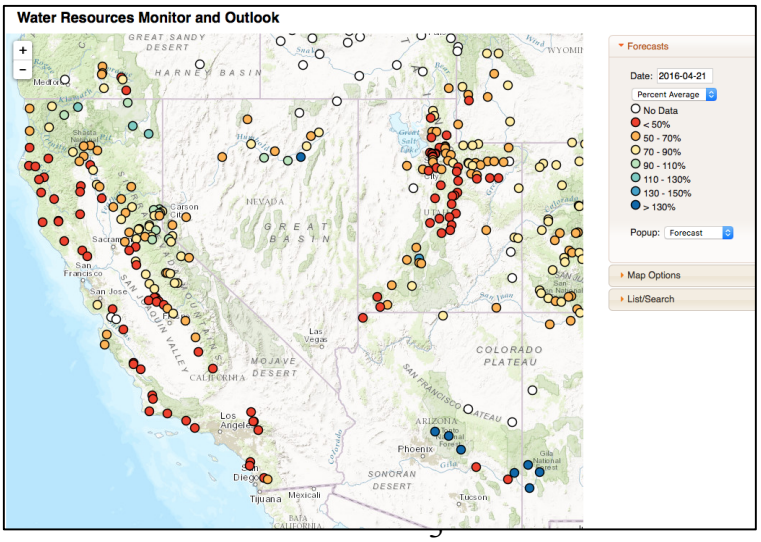

Figure 2. The WRMO webpage will open with a map that provides at a glance information on the percent average forecast flow at that point, over a given time period, or other user-defined information. The landing page prototype will show information across the Western United States.

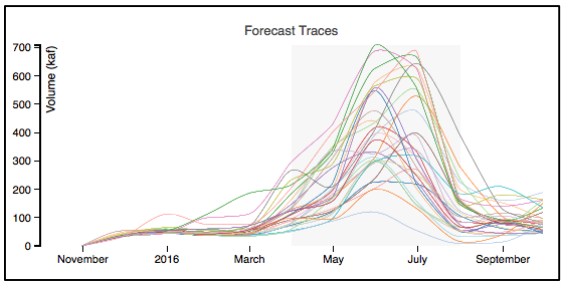

Figure 3. Forecast Ensemble. Thirty traces from a daily run of the hydrologic model initialized on November 1st are shown. These traces are then used to develop probabilistic outlooks illustrated in Figure 4.

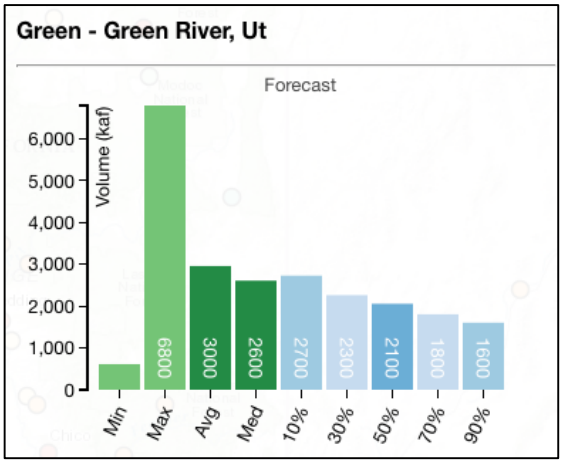

Figure 4. Probabilistic Water Supply Forecast for the Green River at Green River, UT. Green bars on the left show the minimum, maximum, average, and median flows for the past 30 years. Blue bars (right) are based on the traces in Fig. 3, and show probabilities of exceedance for flow volume 50% exceedance level analogous to the median flow (also known as most probable volume), and 10% exceedance indicating that that flow level is only exceeded in one in 10 of the forecast traces (i.e. the upper range of the forecast flows), and 90% indicating that 9 of 10 of the traces exceed that amount (the low range of the forecast). Forecasts shown are for April-July flows, but the user can define the forecast period, or choose other forecast points.

A challenge has been to build a system that takes in and stores large datasets on a daily basis from RFCs and allows statistical analysis and generation of products on demand by interface users. This information, presented via a consistent interface and formats across western RFC domains, includes:

- improved information, products, services, and tools that enable water resources managers to better manage the resource, improve planning, and help develop more prepared and resilient communities
- products generated from real-time hydrologic modeling systems that incorporate hydrometeorological data and short, medium, and long-range weather and climate forecasts
- ensemble forecasts, data analysis for both observed and forecast data, and verification tools for a wide range of time periods relevant to water management
- information and data to contextualize the existing products
- links to integrate the product with other relevant information portals, e.g. the NIDIS Drought Portal

5. VISION FOR THE FUTURE

In FY17, the team and will conduct stakeholder studies and engagement, and will begin developing the seasonal element of the project. Guided by a social scientist on the team, we are introducing the WRMO and products to stakeholders involved in the NIDIS California-Nevada and Colorado River Basin Drought Early Warning Systems (DEWS), and test and refine designs for tools. We will evaluate success by tracking and documenting the use, non-use, and intended use of the products in policy planning exercises—such as the development of risk scenarios—and integration of this information into long term planning and management decisions. This information on evaluation and feedback will be used to refine the products. Finally, the team is beginning development of a seasonal outlook product for water managers, with the goal to provide predictions of cool season accumulated precipitation in the key regional watersheds important for water resources. While this product will be based on existing CPC products, we anticipate that it will be a multi-year applied research and development effort.

Acknowledgements: Funding for this project was provided by the National Integrated Drought Information System (NIDIS), and base funding from NOAA PSD, the RFCs, and CPC.

6. References

Dilling and Berggren. 2012. What do stakeholders need to manage for climate change and variability? A document-based analysis from three mountain states in the Western USA. *Reg Environ Change*. DOI 10.1007/s10113-014-0668-y,

Dilling, L, and MC Lemos. 2011. Creating Usable Science: Opportunities and Constraints for Climate Knowledge Use and Their Implications for Science Policy, *Global Env. Change* 21: 680–89.

Gordon et al, 2016. Navigating Scales of Knowledge and Decision Making in the Intermountain West: Implications for Science Policy, In: *Climate in Context: Science and Society Partnering for Adaptation*. A. Parris et al, eds. Wiley.

Lemos, MC, et al. 2012. Narrowing the climate information usability gap. *Nature Climate Change* 2: 789–794. doi:10.1038/nclimate1614

McNie, E. 2014. Evaluation of the UCRB NIDIS effort, www.nidis.gov.

Michaels, S. 2009. Matching knowledge brokering strategies to environmental policy problems and settings. *Environ. Sci. Policy* doi:10.1016/j.envsci.2009.05.002.

Ray, A.J. and Webb, R.S. 2016. Understanding the user context: decision calendars as frameworks for linking climate to policy, planning and decision-making, In: *Climate in Context: Science and Society Partnering for Adaptation*. A. Parris et al, eds. Wiley.

USGS. 2005. Changes in Streamflow Timing in the Western United States in Recent Decades. USGS Fact Sheet 2005-3018, from the National Streamflow Information Program

Werner, K., et al. 2015. California drought: 2014 service assessment. US Department of Commerce, 62 pp. (http://tinyurl.com/nb2qcz9)

Western States Water Council. 2014. Position #366 – Supporting Federal Research and Development of Updated Hydroclimate Guidance for Floods and Droughts (July 18, 2014), www.westernstateswater.org/policies-2/.