RECLAMATION Managing Water in the West

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The Knowledge Stream

Research Update

Getting a Handle on Streamflow Prediction Skill

What are the sources of uncertainty in streamflow predictions and how do these vary?

Bottom Line

The project helps quantify the importance of knowing current watershed conditions versus having accurate meteorological forecasts to support skillful streamflow predictions in different seasons and indicates the relative value of efforts to improve watershed knowledge and meteorological forecasts from the perspective of water resources management.

Better, Faster, Cheaper

Streamflow forecasts at daily to seasonal lead times are a critical component of the information used to manage water in the U.S. Understanding variations in the skill and uncertainty of streamflow predictions will help water managers make more informed use of predictions and guide strategic investments toward filling key information and prediction gaps.

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Collaborators

- **Reclamation's Technical Service Center**
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Problem

Every day, streamflow forecasts are used to support decisions by reservoir operators and water managers in the United States (U.S.), who must balance a range of competing objectives. At local scales, these decisions might include preventing floods by capturing water, maintaining cool stream temperatures for fish by releasing water, or delivering water to irrigators through scheduled releases. At large regional scales, decisions to store or release water may affect the available supply and water markets for large U.S. cities or growing regions situated hundreds of miles from the water's headwater source, or even have international treaty implications. The need for better short-term forecasts—from minutes to seasons—is perennially raised in studies related to water management. However, identifying the research necessary to improve hydrologic monitoring and prediction products requires identifying the overlap between user needs and opportunities to improve hydrologic monitoring and prediction products.

Solution

A User Needs Assessment

To address the first challenge—identifying user needs—Reclamation and the U.S. Army Corps of Engineers (USACE) recently joined with the National Oceanic and Atmospheric Administration's National Weather Service (NWS) to develop a report entitled, "Short-Term Water Management Decisions: User Needs for Improved Weather and Climate Prediction Information" Raff, et al., 2013 (ST Doc). The ST Doc defined how different weather and hydrologic information products are currently used to support different water management decisions and highlighted information gaps identified by water managers in the two agencies.

Boulder Creek near Folsom Street (Boulder, Colorado) during the September 2013 flood event. These floods were remarkable because of both their large geographical extent and long duration of heavy precipitation. This project will help identify opportunities to improve prediction of events such as this. Photograph by Pablo Mendoza.

Steps Toward Understanding Hydrologic Predictability

To begin to confront the second challenge—identifying opportunities to improve hydrologic monitoring and prediction products—the National Center for Atmospheric Research (NCAR), Reclamation, and USACE are undertaking a comprehensive predictability assessment to quantify and document the major sources of skill and uncertainty in hydrologic prediction products. The design of the proposed project centers on quantifying the impact of different sources of uncertainty on different types of forecasts (e.g., daily to weekly flow forecasts, 3-month volume forecasts), at different forecast initialization times throughout the year (e.g., forecasts starting on October 1st versus April 1st), and in different hydroclimate regions (e.g., regions with or without substantial snow storage or regions with varying degrees of climate

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predictability). Contrasting the Reclamation-USACE assessment of user needs in the ST Doc with an assessment of the opportunities to improve hydrologic prediction products can help frame future research priorities that will ultimately provide better forecasting inputs for decisionmaking.

Application

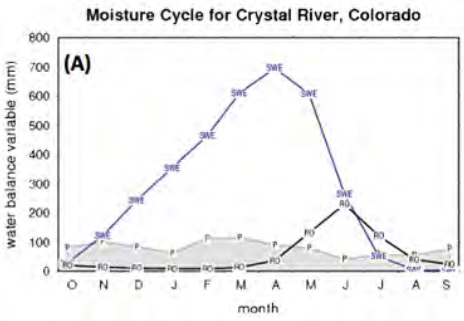
Hydrologic forecast skill depends on both the accuracy of the basin initial watershed condition estimates and their impact on the basin streamflow response and the accuracy of the weather and climate forecasts. An existing framework to quantify the influence of accuracy in these areas (Wood and Lettenmaier, 2008) contrasts the effects of complete (climatological) uncertainty versus perfect knowledge in each predictability component, recognizing that these are merely end-points between which operational predictions lie. That is, real-world forecasts have imperfect knowledge of watershed initial conditions and of weather to climate forecasts.

The predictability study expands this framework to explore the impacts of different levels of initial condition and future forcing uncertainty on streamflow prediction skill, using an assessment of retrospective forecasts ("hindcasts"). The project focuses on approximately 600 relatively unimpaired watersheds across the contiguous U.S. These basins are of "intermediate" size (typically between 1,000 and 10,000 square kilometers), and provide a good sampling of the differences in climate, vegetation, topography, and soils throughout the contiguous U.S. The NWS hydrologic forecast model (Sacramento/Snow17) has been calibrated to these basins using objective methods, and seasonal hindcasts initialized on the first day of each month are being run.

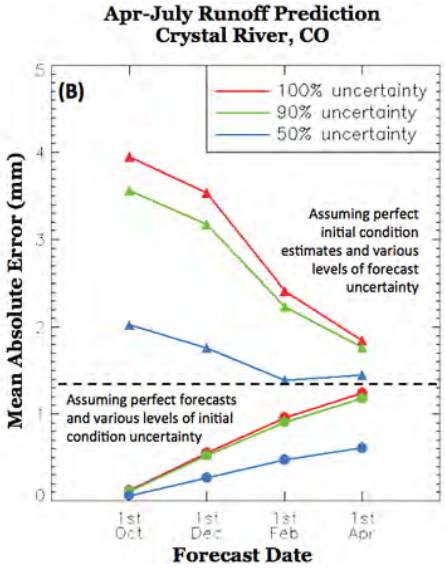
Initial findings agree with earlier work and operational wisdom—for instance, that seasonal streamflow prediction skill depends strongly on initial conditions in the winter and spring, and on weather and climate forecasts in the late summer through the fall, in the snowmelt driven basins of the Western U.S. The work has also suggested new insights—for example, one unexpected finding is that even minor improvements in climate forecast skill can have proportionally larger benefits for streamflow prediction, depending on the time of year and location.

Future Plans

The idealized predictability assessment described above will lay the groundwork for the project's next steps: using state-of-the-art weather and climate predictions and an assessment of actual forecast model to untangle and quantify current actual levels of uncertainty in weather and climate forecasts and initial conditions, and to target the most beneficial areas for efforts to reduce uncertainty. A series of case studies will examine the potential impact of such efforts for water management decisions, and provide insights for strategic decisions on forecasting or monitoring research to operations transition efforts.



(A) The western US water cycle, in which winter precipitation (P) winter accumulates as snow (SWE) and later melts as runoff (RO), means that minor improvements in forecast skill can add up. (B) Even a 10 percent reduction in forecast uncertainty (diamonds) early in year can have larger impact than improving initial watershed condition estimates by the same percentage (circles) throughout most of the water year.



"Understanding sources of skill in streamflow prediction, from basin observations to weather and climate forecasting, will help steer our investments in streamflow forecasting improvements to benefit water users."

Levi Brekke
Water and Climate Research Coordinator

More Information

Wood, A.W. and D.P. Lettenmaier. 2008. *An ensemble approach for attribution of hydrologic prediction uncertainty*. Geophysical Research Letters, Article Number L14401, DOI:10.1029/2008GL034648.

Raff, D., L. Brekke, K. Werner, A. Wood, and K. White. 2013. *Short-Term Water Management Decisions: User Needs for Improved Climate, Weather, and Hydrologic Information.* Technical Report CWTS-2013-1. Bureau of Reclamation, U.S. Army Corps of Engineers, and National Oceanic and Atmospheric Administration. Available at:

http://ccawwg.us/docs/Short-Term_Water_Management_Decisions_Final_3_Jan_2013.pdf)

Crystal River, Colorado (source: http://growingupfortcollins.com).