Research Update

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Improving Snowmelt Models to Improve Operations in a Shifting Climate

Can a physically based snowmelt model provide more reliable water supply and runoff forecasts?

Bottom Line

This research study explored potential ways to improve reservoir inflow forecasts with a physically based snowmelt model.

Better, Faster, Cheaper

Reservoir operations in snow-dominated or snow-to-rain transitional basins rely on snowmelt-driven streamflow forecasts. Improved modeling techniques that use physically driven snow models that do not rely on stationary statistical relationships can improve the reliability of water supply and inflow forecasts.

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Problem

Pacific Northwest reservoirs get runoff from either rain or snow, and sources that vary widely from basin to basin and year to year. Reclamation water managers rely on water supply forecasts to water supply variability with water storage, delivery, and flood control. Now, streamflow forecasts for snowmelt are typically largely based on historic trends and observations. These models rarely contain a physical basis and have been shown to become unreliable when non-normal conditions are encountered. Further, recent climate modeling has shown a shift in the Pacific Northwest to decreased snowpack accumulation, transition to rain, earlier runoff, and increased water demand associated with prolonged irrigation seasons. Models using physics-based parameters can simulate non-normal climate conditions and could be used to evaluate streamflow responses to short-term extreme events such as rain-on-snow; extended effects of unseasonable wet, dry, warm, or cold periods; and the long-term effects of climate warming.

Solution

This Reclamation Science and Technology Program research study, a collaboration between Reclamation and the U.S. Department of Agriculture's Agricultural Research Service, used iSnobal to test potential forecast improvements for these changing conditions. A physically based model, iSnobal calculates all mass and energy fluxes that affect the snow cover from the governing physics.

Application and Results

Researchers applied iSnobal within central Idaho where Reclamation's Anderson Ranch and Arrowrock Reservoirs and the U.S. Army Corps of Engineer's Lucky Peak Reservoir work as a system to provide flood control, water delivery, environmental flows, recreational reservoir levels, and downstream flows for fish.

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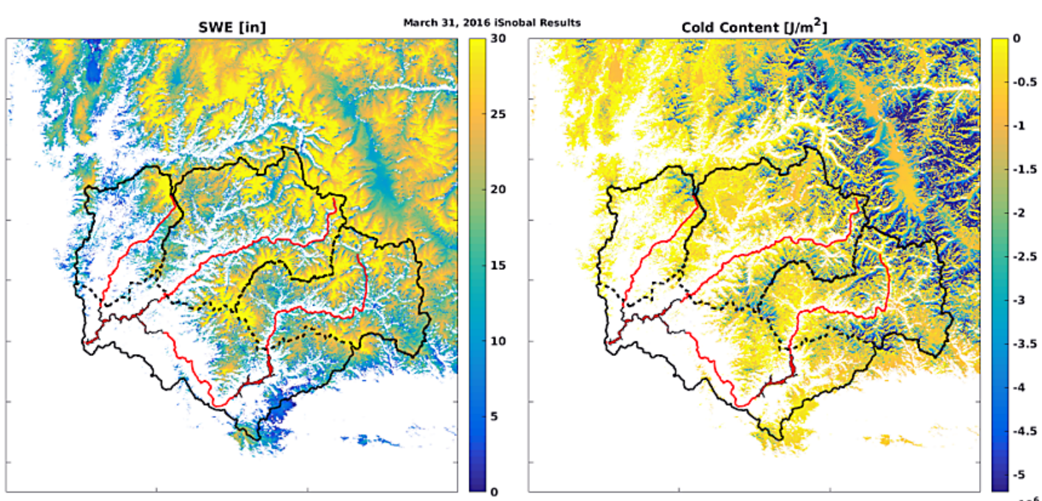

Current modeled SWE on the left and cold content on the right, with yellow indicating that the snowpack is close to or already melting.

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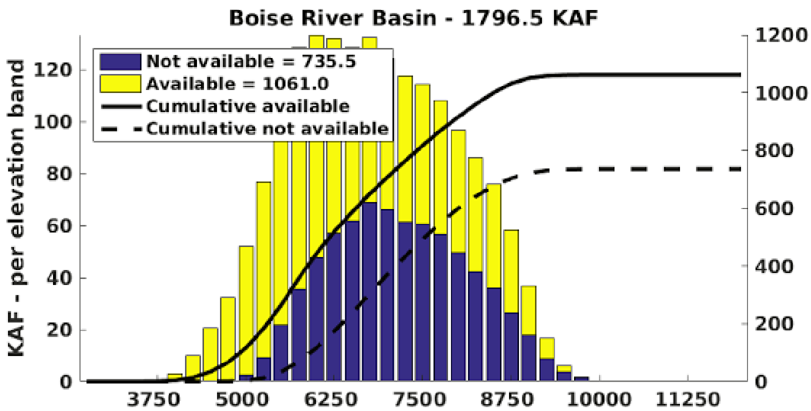
In addition to snow distribution and melting, iSnobal provided useful information on how much Snow Water Equivalent (SWE) was in the basin. River and Reservoir Operations staff in Reclamation's Pacific Northwest Region reviewed weekly maps of the Boise River Basin SWE and cold content and compared these to traditionally used snow information.

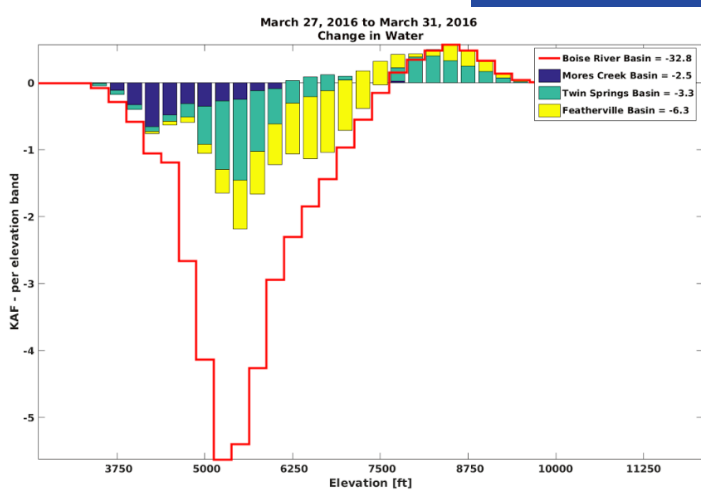


Potential water available or not available for melt as a function of elevation in the Boise River Basin as of March 31, 2016. The solid and dashed lines are the cumulative sum of water volume.

In the final 2 years of the research study (water years 2015 and 2016), researchers coupled three physically based models (iSnobal, Weather Research and Forecasting Model, and Distributed Hydrology-Soil-Vegetation Model) to demonstrate the potential of using output from a short-term weather forecast and snowmelt model to produce streamflow forecasts. These 2 water years had non-normal (early) melt that this research study captured well. This proof-of-concept project demonstrated that integrating different physical snow models could provide an accurate 3-day reservoir inflow forecast. Modeling results were shared with many water resource stakeholders, and the 3-day reservoir inflows were shared with the Northwest River Forecast Center (NWRFC). Results from the 3-day reservoir inflows compared well to the NWRFC forecast products.

Future Plans

In the future, it will be important to test the application over a variety of water years, improve streamflow modeling by testing other hydrologic models, and integrate model outputs with resource agencies that provide real-time river forecasts. Although there are many potential benefits of incorporating physical snow models into runoff forecasting, there are several challenges associated with running and relying on such models for water operations.



Change in water volume from March 27 to 31, 2016, model results as a function of elevation, calculated from change in SWE.

These snow models limit the simplifying assumptions built into conceptual models and therefore require more input data (both temporal and spatial) to run. These requirements can be difficult to achieve on a consistent basis in real-time operations. Additionally, the increased spatial and temporal resolution often provided by physical models needs appropriate observations to validate the simulations. For example, high-resolution SWE estimates across a large watershed may not be accurate (or useful) if they have been compared to only a limited number of snow measurements and/or survey locations within the watershed.

Operational routines for snow-dominated or snow-to-rain transitional basins may benefit from integrating distributed, physics-based snow models. These models are more robust to climate extremes and change and provide spatial information that current operational rainfall-runoff models do not provide. Estimates of distributed SWE and liquid water volume simulations at the soil surface obtained from iSnobal have already added information about in-basin snow conditions and provided a context for current forecasting methods.

"Integrating a physically based snowmelt model into an operational routine will improve the knowledge of basin snow conditions in extreme water years, especially considering a changing climate. The potential to improve the quality of currently used seasonal water supply forecasts by integrating a distributed, physics-based snowmelt model could improve forecasts in the short term. This could also provide a foundation for more complicated integrations attempted in this research study."

Ted Day
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Collaborators

- **Snake River Area Office in Reclamation's Pacific Northwest Region**
- **U.S. Department of Agriculture's Agricultural Research Service**

More Information

www.usbr.gov/research/projects/detail.cfm?id=2264

For printable version see: www.usbr.gov/research/docs/updates/2016-20-snowmelt-models.pdf