RECLAMATION Managing Water in the West

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The Knowledge Stream
Research Update

Improving Water Management With a State-of-the-Art Snow Model

A physically based, high resolution snow model for enhanced streamflow predictions in a changing environment

Bottom Line

Traditional river forecasting tools based on historical trends are struggling to cope with today's evolving climate. Models based on physical principles can handle such non-normal patterns. This research project helps determine their suitability for river management.

Better, Faster, Cheaper

This modeling approach can answer the vital questions faced by water managers throughout the snow season: how much water remains in the snowpack, how susceptible it is to melt, and when and where that melt water will enter the river system—no matter what the weather conditions.

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Problem

Current operational snowmelt-driven streamflow forecasts are largely derived from models based on statistical analyses of historic trends, such as the relationship of point observations of snow water equivalent to streamflow volume. Up until now, the reasoning has been that the computational demands of modeling over large basins required simpler, parameterized models. Often, a temperature-index melt model based solely on air temperature and historic melt patterns is used to forecast or analyze snowmelt rates. This simplified method is employed because it is computationally fast and air temperature data are readily available.

However, these statistically based models lack a strong physical basis. Snowmelt is a product of many physical processes such as sun, wind, and heat that depend on more than just air temperature. It has been shown that models without a physical basis become unreliable when non-normal conditions are encountered. Recent unseasonably warm winters have exposed the inadequacies of current modeling tools and clearly demonstrate the need for modernization.

Physically based distributed snow models (PBDSM) are founded on the physical processes governing snow accumulation and melt. PBDSMs require little to no calibration and are based on current and predicted conditions. The physical basis means that all mass and energy fluxes that affect the snow cover are numerically calculated based on the governing physics. These models readily adapt to changing conditions and are ideal tools for evaluating streamflow responses to short-term extreme events such as rain-on-snow; the extended effects of unseasonable wet, dry, warm, or cold periods; and the long-term effects of climate warming.

A lack of driving data (for example, mountain weather observations) for PBDSMs has also been seen as an impediment to more complex solutions. Today, however, computational capabilities have increased exponentially, efficient techniques for distributing limited observations have been developed, and gridded weather forecasts are readily available.

Solution

iSnobal is a PBDSM that has been successfully applied and tested in research basins throughout the world. The model independently resolves all the mass and energy fluxes affecting snow accumulation and melt while tracking the snowpack state (e.g., how susceptible is the current snowpack to melt). The model was designed for hydrologic applications and is forced with commonly measured or modeled meteorology.

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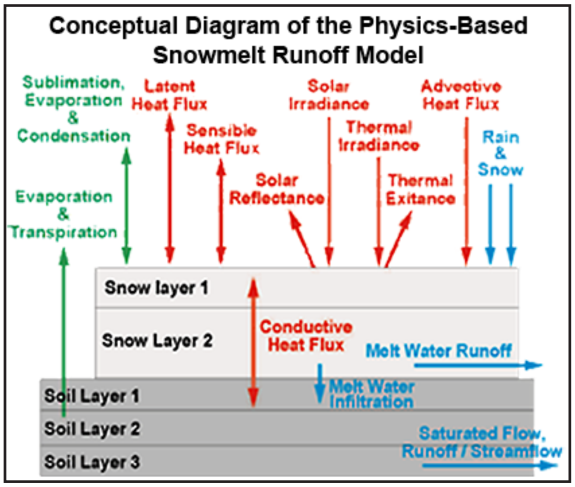

Schematic of the physical processes considered in iSnobal.

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This Reclamation Science and Technology Program research project applies iSnobal in an operational setting for the first time ever. The test application is in the Boise River Basin, Idaho, covering a model domain of 13,000 square kilometers (km^2). Three major reservoirs capable of storing close to a million acre-feet of water are located in the basin. Snow accumulation and melt is simulated with 0.01 km^2 resolution (100 x 100 meters)—100 times finer than the current SNODAS snow model from the National Weather Service. Project goals are to assess the feasibility of PBDSM applications in operational settings, determine how applications might be improved, and outline how water managers can best leverage modeling capabilities.

Application and Results

In 2013 and 2014, up-to-date iSnobal products were distributed to Reclamation on a weekly basis throughout the snowmelt season. Products included gridded snow distribution across the Boise River Basin, summations of snow storage above each of the three reservoirs by elevation, and maps of melt susceptibility. It was demonstrated that sufficient forcing data were available and that iSnobal products could be generated in a timely fashion compatible with operational needs.

Future Plans

Work is nearly complete on coupling a hydrologic routing model to iSnobal to convert simulated snowmelt and precipitation to streamflows entering the reservoir network. In 2015, short-term weather forecasts generated by the Weather Research and Forecasting (WRF) model will be input to the combined snow-routing model. These final steps will produce the most sophisticated modeling framework in the world for predicting snowmelt-generated streamflow on an operational basis.

Reservoir managers will have an advanced, modern tool for predicting inflows, optimizing water management, and increasing flood protection in all possible conditions. These modeling tools are not just specific to the Boise River Basin—the physical principles they are based on make them directly applicable to snow-fed basins throughout North America and beyond.

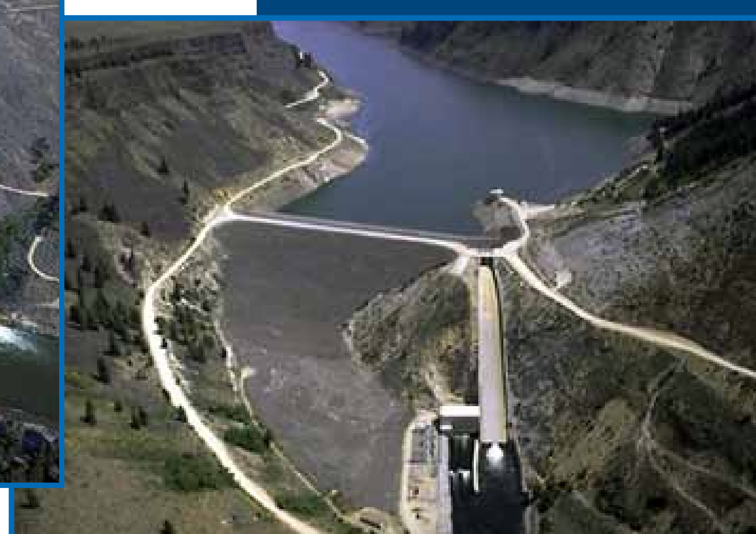
"We have already been able to use model results to support real-time operations for the Boise River Basin. The graphics and numerical products depicting distribution and amount of available snowmelt water were very useful in confirming our suspicions that runoff in both 2013 and 2014 would be less than forecasted, and less than what Snotel data alone would indicate."

Mary Mellema
Hydrologist, Reclamation's Pacific Northwest Region

More Information

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

Lucky Peak Dam and Reservoir, Idaho (a U.S. Army Corps of Engineers facility operated as a system with Reclamation's upstream Arrowrock Dam and Reservoir).



Anderson Ranch Dam and Reservoir, Idaho.