U.S. Department of the Interior
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Research and Development Office
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Merging High-Resolution Airborne Snowpack Data with Existing Long-Term Hydrometeorological Observations to Improve Water Supply Forecasting

Research Bulletin
S&T Project 8116

Mission Issue

As drought continues in the western United States, development of resilient local supplies and augmentation of drinking water reservoirs with advanced treated recycled water, or SWA-IPR, is becoming an ever-larger component of water resource planning.

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Problem

Measuring mountain snowpack has long been central to seasonal streamflow forecasting in the Western United States. Traditionally, snow measurements are taken manually or by automated monitoring stations that only observe one location. These locations are typically limited to areas that can be safely accessed and tend to be in similar elevations bands that were historically relevant for water managers. Recent advances in airborne remote sensing have added tremendous observational capacity through increased spatial resolution and coverage across otherwise inaccessible topography. The spatial coverage allows water managers to understand snowpack patterns across the landscape, and therefore build climate resiliency in the face of changing snow accumulation and melt patterns.

Recent advances in observational ability, however, have outpaced research toward developing efficient and cost-effective strategies for leveraging the new high-resolution data in streamflow forecasting systems. Existing forecasting methods rely on calibrated hydrologic models or statistical approaches, both of which benefit from the longer observational records available at index stations. Hydrologic model calibration often compensates for biases in snowpack representation or precipitation inputs, and it is not yet known how new spatially detailed measurements can improve these model forecasts.

Solution

Airborne Snow Observatory (ASO) datasets are an example of high-resolution snow products that are not yet widely used in streamflow forecasting models. ASO uses a plane-mounted lidar and imaging spectrometer to drive a licensed workflow that provides snow depth, snow water equivalent (SWE), and albedo. ASO also updates a distributed snow model called iSnobal, that can provide snow density for calculating SWE from snow depth and can be used to provide snow estimates between flights when run continuously.

Collaborating with researchers at the National Center for Atmospheric Research (NCAR), this project explores the value of using existing ASO measurements to support water supply forecasting in the Tuolumne River basin, with a focus on: 1) evaluating the use of ASO to support snow statistical analyses, 2) evaluating the use of ASO for statistical water supply forecasting methods, and 3) evaluating the use of ASO in dynamical Ensemble Streamflow Prediction (ESP) frameworks.

"When [the system] was built 100 years ago, you could look outside your window if you're in Colorado and see snow, and know that that's your reservoir for the spring...It's not like that anymore. What you're seeing there is just a completely different way in which the system is managed."

Camille Touton,
Commissioner,
Bureau of Reclamation

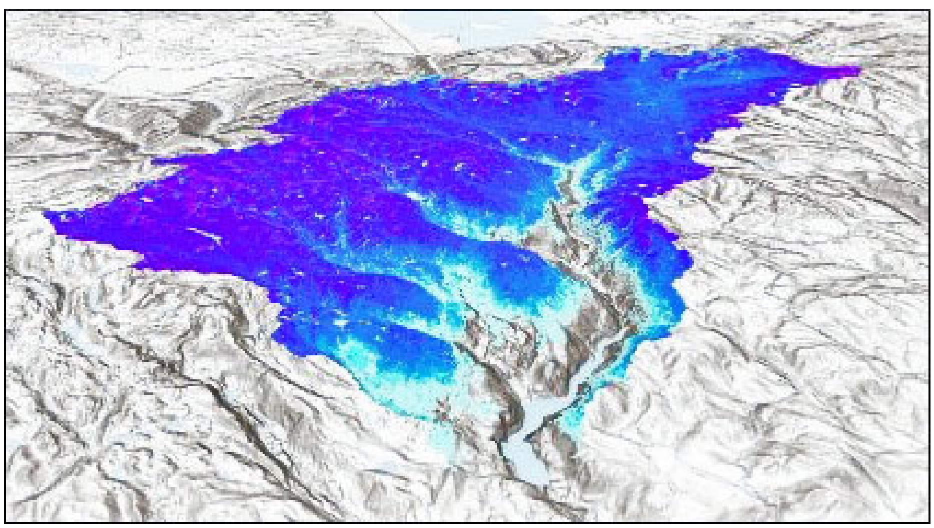
More Information

https://www.usbr.gov/research/projects/detail.cfm?id=8116

Application and Results

Snow statistical analyses predict basin mean SWE by combining ASO flights, which represent a point in time when the flight was flown, with ground station data, which are continuous in time. The analyses also identify where additional in-situ snow monitoring stations can be located to best improve estimates of basin-wide SWE. Analysis from the Tuolumne indicates that approximately 5-10 ASO flights, combined with stations, are sufficient to define 96% of the variability in the basin-averaged SWE from the remaining flights. However, this relationship starts to break down for times with very high or low SWE conditions, indicating that more flights or additional products are needed to improve the estimation of that relationship. Adding a new station at very high elevation would improve these relationships.

Assimilating ASO in a calibrated Structure for Unifying Multiple Modeling Alternatives (SUMMA) watershed model improved model volume forecasts, even with a relatively simple direct insertion approach that directly replaces the modeled snow states with the observations. Flights near peak SWE correct errors in winter precipitation and provide the most improvement in model forecast skill, while subsequent scenes provide less improvement and may even reduce model skill if not assimilated carefully. Other assimilation approaches (e.g. Ensemble Kalman Filter) that update more model states may support further forecast improvement. Increasing resolution and the representation of late season (high elevation) model snow will likely also improve late season simulation.



Future Plans

The methods developed in this work are currently being expanded with funding from the Snow Water Supply Forecasting Program. Expansion includes consideration of other spatially distributed datasets, such as stereo-optical snow depth, and generalization of the statistical scripts for use in other locations. Scripts will be made available through the Reclamation gitlab page for Reclamation use here:

https://gitlab.bor.doi.net/8210/extending-aso.