POTENTIAL IMPROVEMENTS TO COLORADO BASIN RIVER FORECAST CENTER WATER SUPPLY FORECASTS USING EXTERNAL SNOW PRODUCTS

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ABSTRACT

The amount of water stored as mountain snow is the primary driver of seasonal (April through July) streamflow volumes in the Upper Colorado River and Eastern Great Basins. The Colorado Basin River Forecast Center (CBRFC) publishes seasonal, volumetric water supply forecasts starting in January for spring runoff volumes. CBRFC streamflow forecasts are used to provide impact-based decision support services throughout the region. The CBRFC continually seeks to improve their forecasts by incorporating new information into their hydrologic forecast system. To this end, the CBRFC is investigating the usability of external snow products in the current forecasting system. The CBRFC conducted an error attribution analysis to compare the uncertainties in April 1st water supply forecasts related to CBRFC hydrologic model errors and unknown future spring weather. Errors in model snow states are some portion of the larger model errors, along with errors from model soil moisture states, calibration parameters, model structure, etc. Results indicate that on average, roughly half of the forecast error in an April 1st water supply forecast is attributed to the unknown spring weather. It follows that improvements in model April 1st snow states can be expected to improve some portion of the other half of the April 1st forecast error. (KEYWORDS: streamflow forecasts, operational forecasting, forecast error, river forecast center, remote sensing of snow)

INTRODUCTION

The National Weather Service's Colorado Basin River Forecast Center (CBRFC) is tasked with providing volumetric water supply forecasts at 174 locations to Colorado River Basin and Eastern Great Basin stakeholders. Water supply forecasts include errors and uncertainty from a variety of sources. A knowledge of the sources of error that contribute to uncertainty in water supply forecasts provides a framework for education and targeted research.

Water supply forecasts aim to predict the unregulated volume of water that would flow past a stream location between the beginning of April and the end of July, absent anthropogenic effects such as diversions or reservoir regulation. Official water supply forecasts are provided monthly or twice monthly from January to June and are intensively quality controlled by forecasters. Model guidance is available daily. The CBRFC uses a combination of lumped parameter models including SNOW-17 (Anderson, 1976), the Sacramento Soil Moisture Accounting model (Burnash et al., 1973), and a unit hydrograph model. These models are recalibrated every 5 years.

Forecasts are presented in terms of exceedance probabilities, with the 50% exceedance probability being the most probable forecast. The distribution of possible volumetric forecasts is created by using 30 to 35 years of historic forcing data (air temperature and precipitation) to run the model forward from the current day to the end of the July. This distribution of probabilities is updated every day using the current model states and provided to the public and stakeholders as 'model guidance'. The distribution of volumes obtained by this method quantifies the uncertainty in forecast due to unknown future weather. However, there are is additional uncertainty in the forecasts due to model error. Model error includes, but is not limited to, errors in model snow and soil moisture states, error in model structure, and error in model parameters.

The CBRFC continually aims to improve water supply forecasts for stakeholder decision support purposes. Recent years have seen an increase in the availability of snow products over the Colorado River Basin. The CBRFC intends to evaluate the potential for these and other external datasets to improve water supply and short term

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forecast products. External snow products have the potential to correct for some portion of the model error associated with current model snow states. The Snow Water Artificial Neural Network (SWANN) product (Broxton et al., 2019) was evaluated using the current CBRFC forecasting system, and although the snow water equivalent (SWE) from SWANN was similar to SNOW-17 SWE in most instances, incorporation did not consistently improve CBRFC forecasts (Butler, 2021).

METHODS

Total forecast error is a combination of model error and unknown future weather error. A study was performed to quantify the distribution of these sources of uncertainty in four test basins: inflow to Taylor Park Reservoir, Uncompahgre River inflow to Ridgeway Reservoir, Gunnison River inflow to Blue Mesa Reservoir, and East River at Almont, CO. Total forecast error is quantified from 35 years of reforecast data (1980-2015) for the April 1st forecasts. For this study, we use the mean absolute difference between the observed and forecast volumes to represent total forecast error. Model error is quantified from 35 years of calibration data over the same time period. For this study, the mean value of the absolute difference between observed and calibration model volumes is used to represent the model error. Since the total error is the sum of the model error and unknown future weather error, a simple difference (residual) quantifies the unknown future weather error.

A qualitative examination of Airborne Snow Observatory (ASO) SWE data was performed for the 2018 and 2019 water years at the East River at Almont, CO. This study compared SNOW-17 SWE to ASO SWE at the time of the overflight closest to peak SWE. The difference between SWE values was then compared to the difference between observed and simulated streamflow volumes to make a qualitative assessment of the potential for ASO data to improve the CBRFC water supply forecast.

RESULTS AND DISCUSSION

Approximately half of the volume error in April 1st water supply forecasts is due to unknown future weather and the other half is due to model error at the four test basins in the Upper Colorado River Basin. This provides a useful framework when considering improvements to CBRFC water supply forecasts. Research projects will often target one of these broad categories for improvement. For example, research on seasonal to sub seasonal weather forecasting or Climate Indices would target improvement to uncertain future weather. In contrast improvement to the modeled snow states in the CBRFC's operation model would target some portion of the model error. Since model error is a combination of many sources of error, an improvement to the model snow states would improve some portion of the model error. However, it is more difficult to parse the portion of model error attributed to different components.

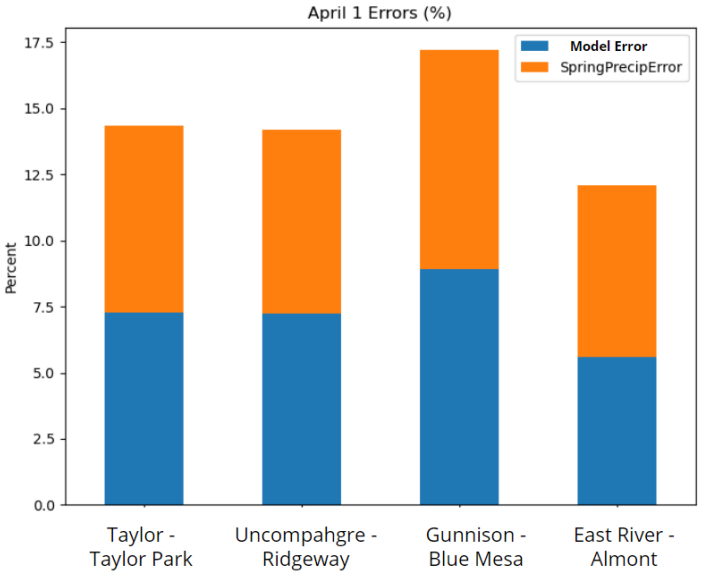

Figure 1. April 1 water supply forecast error at the CBRFC attributed to model error and future weather uncertainty at 4 test basins.

ASO data was evaluated for the 2018 and 2019 water years for the East River at Almont, CO in the larger Gunnison River Basin (Table 1). The East River basin is divided into 3 hydrologic response units based on elevation (below 2896m, between 2896m and 3354m, and above 3354m). The 2018 water year was a dry year, where the April through July streamflow volume was 42% of the 1980-2010 average. The CBRFC calibrated model over simulated the 2018 volume. ASO SWE suggested a substantial decrease in the upper elevation zone SWE, which suggests the potential for improving the simulation. The 2019 water year, in contrast,

was a wet year. The observed volume was 148% of the 1980-2010 volume. The CBRFC calibrated model under simulated the April through July volume. ASO data suggested a substantial increase in the middle elevation SWE, which again would have the potential to improve the simulation. A more intensive

	Volume (kaf)		Snow Water Equivalent (mm)		
Flight Date	Calibration	Observed	Zone Elevation (m)	Calibration	ASO
Mar 31, 2018	89	77	Upper: 3354-4334	472	381 ↓
			Mid: 2896-3354	185	211
			Low: 2444-2896	20	41
Apr 7, 2019	235	269	3354-4334	932	930
			2896-3354	478	569 ↑
			2444-2896	239	231

Table 1. Qualitative evaluation of ASO SWE data for the 2018 and 2019 water years suggesting the potential for improving CBRFC water supply forecasts.

study of the effects of incorporating ASO SWE into CBRFC's current forecasting system is warranted to quantitatively evaluate ASO SWE data on water supply and short-term forecasts.

In addition to quantifying the error associated with various aspects of the CBRFC's hydrologic model, this work aids in the understanding of how much potential improvement to seasonal volumetric water supply forecasts can be expected from new external data sources. While new external products may have the potential to significantly increase the skill in seasonal forecasts, there is not a single product that will address all sources of forecast error. When allocating resources, researchers and basin stakeholders may seek to prioritize projects and efforts that have the potential to significantly reduce error in the forecast process.

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