A testbed to develop, apply, and evaluate advances in in process-based streamflow prediction for water management in the Columbia River Basin

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Water management in the US depends on short range to seasonal and interannual hydroclimate predictions, and it has been a long-standing scientific and technical challenge to advance their skill. The research community has invested substantially in developing better predictions through improved land process modeling and subseasonal to seasonal climate forecasting, yet few of these advances have been adopted by the water management world.

The objective of this project is to implement a system for short-range to seasonal hydrologic forecasting for the Pacific Northwest (PNW) Region based on watershed modeling and ensemble streamflow prediction (ESP) methods. A key motivation is to advance our understanding of the use of retrospective simulations and hindcasting, as well as new supporting techniques such as data assimilation, sub-seasonal climate prediction and new watershed process models to enhance the skill of operational streamflow predictions. The work will create a testbed-like platform for introducing supporting methods that have been shown to increase the reliability and skill of hydrologic analyses and forecasts, and also aid in the development of actionable over-the-loop (more automated) hydrological predictions.

In the first year of this two-year project, we have developed a system that produces real-time ensemble forecasts for both seasonal and short-range (0-30 day) lead times. The system was built from existing, in-progress modeling work that has been funded in part by the U.S. Army Corps of Engineers (USACE) and U.S. Bureau of Reclamation (Reclamation). In particular, a watershed-based implementation of a modeling framework centered on the Structure for Unifying Multiple Modeling Alternatives (SUMMA: Clark et al., 2015a, Clark et al., 2015b) and the MizuRoute channel routing model (Mizukami et al., 2015) has been configured for the entire western U.S. on an intermediate USGS HUC-12 scale (about 100 km2 per watershed). This modeling suite is forced by an ensemble meteorological dataset created using the Gridded Meteorological Ensemble Tool (GMET; Newman et al, 2015), spanning 1970 to real-time (daily updating) at a 3-hourly timestep. Model calibration and forecasting workflows have been developed and applied to the entire PNW region, allowing for seasonal ensemble streamflow hindcasts to be created for river systems. The methods and models for forecasting are combined into an experimentally operational workflow called the System for Hydromet Analysis, Research and Prediction (SHARP), shown in Figure 1. The project has configured and deployed ESP forecasts and multi-decadal hindcasts using this framework for the PNW in a real-time mode at NCAR.

The second year of the project will focus on the analysis and enhancement of ESP forecast information products through the application of additional methods, including bias-correction, post-processing and climate conditioning. Post-processing is commonly used in forecast operations (e.g., by NWS River Forecast Centers), but systematic biascorrection of ESPs (based on historical model bias) is rarely used, and climate conditioning of ESPs is not common. All RFCs use 1 to 10 days of weather forecasts to condition or replace the early lead time inputs to an ESP (which benefits their skill) but few use the capabilities of the NWS Hydrologic Ensemble Forecast System (HEFS) to incorporate sub-seasonal – week 2 to month 2 to seasonal (S2S) climate information. Recent sub-seasonal climate forecasts have increased in skill over the last decade, making it likely that the inclusion of climate information in the 10 to 20 day time frame (or weeks 2-3), as well as for the first season, will benefit ESP forecast skill. S2S climate forecast information also reflects climate trends, which can contribute to the skill of ESP forecasts in comparison to using only historical information (e.g., Lehner et al, 2017). Recent work by the PI (with Reclamation's Upper Colorado Region) to apply National Multi-Model Ensemble (NMME) climate forecasts to condition ESP inflows to Lake Powell confirmed that the strategy can reduce inflow errors (Baker et al., 2021,2022).

The ensemble streamflow forecasts and associated hindcasts can be used to develop forecast information products that support risk-based decision-making, due to their representation of the future flow probabilities and the ability to assess current forecasts in the context of past forecast characteristics and performance. For longer lead times (e.g., out to multiple seasons), it is not possible to predict risks in this fashion for a specific day, but the contrast of the current forecast with similar forecasts from past years (initialized at the same time) can indicate within a coarser period (e.g., one or more months) whether there is an elevated or reduced risk of flows exceeding or falling below a threshold. In combination with current reservoir system states, this risk calculation could be extended to reservoir system storage or release variables.

Throughout the project adjustments to the system and products will be made based on feedback from water managers in the basin and increased understanding of the information conveyed by the products during one or more operational seasons (i.e., through co-development). Outcomes for this two-year development effort will be used to inform future directions of forecasting capabilities and development, and support the uptake of new technologies within the streamflow forecasting communities.

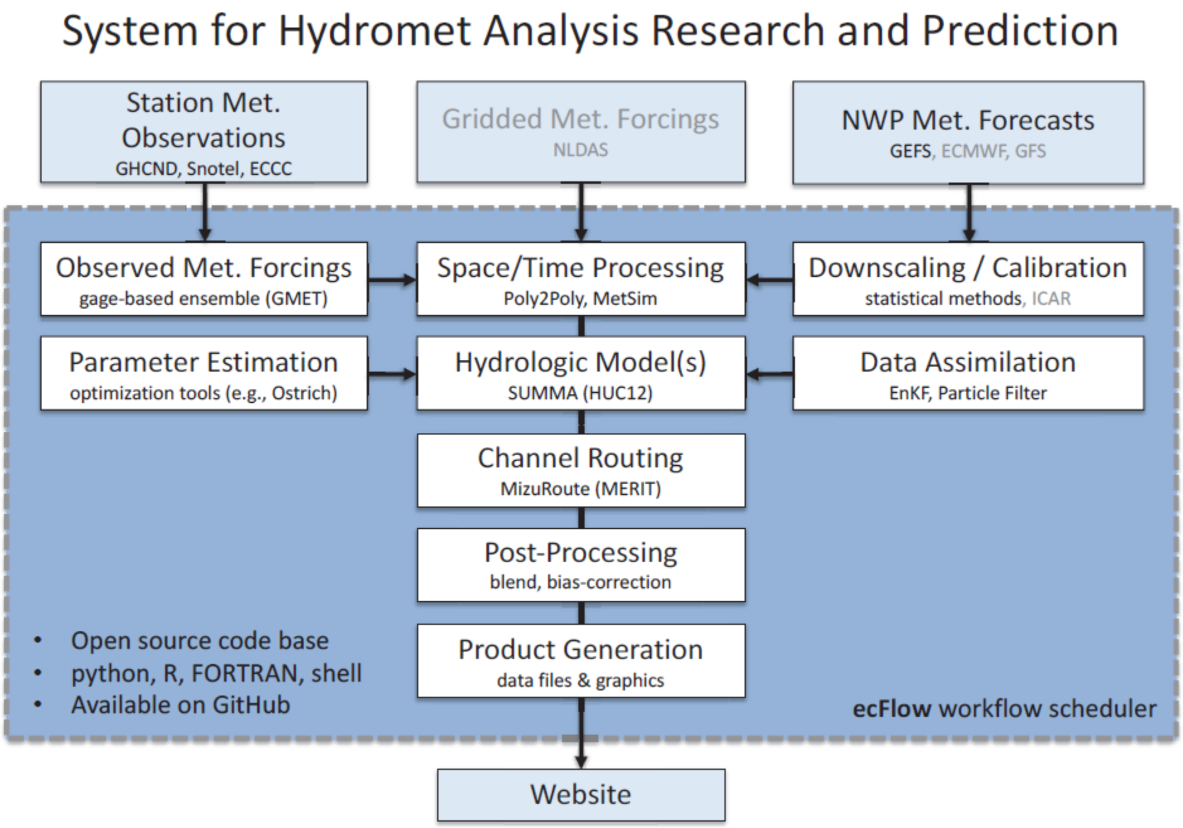

Figure 1. SHARP component schematic. Specific options or tools that are proposed in this project are shown in small print in each component, while several that will not be used are greyed out. The dashed box contains the components that are run within the automated workflow.

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