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Trading off data and parameter uncertainty versus model structure uncertainty: a case study comparing single-model and multi-model ensemble streamflow forecasting

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Developing an ensemble hydrologic forecasting is difficult and time consuming work and choices are often required to determine how much effort is worth expending on one aspect versus another. Assuming an ensemble forecasting system uses ensemble weather forecasts, the key decision at hand is what other sources of uncertainty should be reflected in the ensemble forecast. Options include model structural uncertainty, model parameter uncertainty and model calibration period data uncertainty (e.g., climate inputs or streamflow measurements). A related decision involves whether or not to utilize a distributed/semi-distributed hydrological model in the forecast system in place of an ensemble of easier to construct lumped parameter hydrologic models. On one hand, using an ensemble of lumped models enables consideration of model structural uncertainty in the forecasts. On the other hand, using a more physically-based forecast system is often also appealing. Unfortunately, choosing a distributed model can practically preclude the use of a multi-model ensemble given the construction and calibration of multiple distributed models would be very labour and computationally intensive.

With the above consideration in mind, this study sets out to compare two alternative forecasting systems performance. The first system is a multimodel forecast system relying on 20 calibrated lumped hydrologic models where model structure uncertainty is the only calibration period source of uncertainty considered explicitly. The second forecasting system uses only one of the lumped hydrologic models but constructs the ensemble forecasting system considering both parameter and measured climate data uncertainty (while ignoring structural uncertainty). As such, we evaluate the choice between investing time in either calibrating 19 additional models or instead investing that time into characterizing and accounting for model parameter uncertainty and model calibration period data uncertainty. Previous studies often focus on comparing model structure uncertainty versus model parameter uncertainty. Key to this research is the utilization of an advanced large scale historical ensemble climate dataset developed for the Continental US and the southern part of Canada and publically available at http://ral.ucar.edu/projects/hap/flowpredict/subpages/pqpe.php.

The forecasting systems use the Ensemble Kalman Filter (EnKF) and are applied to 20 Quebec watersheds. All models are calibrated to the same period and then forecasts are all based on the same ensemble weather forecasts. Considering forecasting performance for the entire forecast period, results show the single model system is better considering deterministic performance metrics (using the ensemble means). The multimodel system is better considering probabilistic performance (e.g., reliability) for forecasts with 1-6 day lead times. Considering high flows only (the highest 10% of observed flows during the forecasting period), the single model system produces the highest quality deterministic and probabilistic performance metrics.