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A stochastic data-driven forecasting framework using wavelets for forecasting uncertain hydrological and water resources processes

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This study focusses on the problem of forecasting uncertain multi-scale hydrological and water resources processes through a data-driven stochastic framework that accounts for changes across time and scale. A blueprint for stochastic modeling (Montanari and Koutsoyiannis, 2012) is merged with wavelet transforms (a time-frequency localization method), input variable selection, and data-driven models resulting in the Stochastic Wavelet Data-Driven Forecasting Framework (SWDDFF). The purpose of the proposed SWDDFF is to provide a general tool for generating multi-scale hydrological and water resources processes forecasts with uncertainty assessment.

Within SWDDFF, input variable selection is used to identify the most important time-scale information uncovered by the wavelet transform that is subsequently fed to a data-driven model (e.g., multiple linear regression, neural networks, etc.). Stochastics is used to quantify the uncertainty related to input data, input variable selection, model parameters, and model output (although other sources of uncertainty may be explicitly considered). Uncertainty is estimated in a straightforward manner using the bootstrap while the maximal overlap discrete wavelet transform is adopted for wavelet transformation.

An urban water demand dataset from Montreal, Canada is used to demonstrate SWDDFF in a real-world forecasting problem. Three main sources of uncertainty are explicitly considered in the forecasts: input variable selection, model parameters, and model output. Forecast accuracy and reliability are measured for three cases: 1) model parameters; 2) model parameters and model output; and 3) input variable selection, model parameters, and model output. It is found that the best forecasting performance is obtained when input variable selection, model parameters, and model output uncertainty are considered together. A comparison between SWDDFF and benchmark models, that do not use wavelets, are also considered, demonstrating improved performance when time-scale information is included via wavelet transformation. This study demonstrates that SWDDFF is a promising multi-scale forecasting tool that can be used for quantifying uncertainty associated with hydrological and water resources forecasts; however, further studies are required to assess its usefulness in other contexts such as rainfall-runoff, drought, streamflow, etc.

References

Montanari, A., Koutsoyiannis, D., 2012. A blueprint for process-based modeling of uncertain hydrological systems. Water Resour. Res. 48. doi:10.1029/2011WR011412