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The quest for physically realistic streamflow forecasting models

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The current generation of time stepping hydrological models used by operational forecasting agencies are process-weak, where model parameters are often assigned unrealistic values to compensate for model structural weaknesses. These time stepping simulation models are therefore subject to the same stationarity predicament that plagues statistical streamflow forecasting systems. Consequently, the operational forecasting community has similar research priorities to the science community, that is, to develop physically realistic hydrological models.

This paper describes development of a new modeling framework to improve the representation of hydrological processes within operational streamflow forecasting models. The framework recognizes that the majority of process-based models use the same set of physics – most models use Darcy's Law to represent the flow of water through the soil matrix and Fourier's Law for thermodynamics. The new modeling framework uses numerically robust solutions of the hydrology and thermodynamic governing equations as the structural core, and incorporates multiple options to represent the impact of different modeling decisions, including different methods to represent spatial variability and different parameterizations of surface fluxes and shallow groundwater. Use of multivariate research data to evaluate these different modeling options reveals that the new modeling framework can provide realistic simulations of both point-scale measurements of hydrologic states and fluxes as well as realistic simulations of streamflow in headwater catchments, with minimal calibration. Moreover, the availability of multiple modeling options improves representation of model uncertainty.