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Thesis Proposal

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Rainfall-runoff models, a type of hydrologic model that predicts streamflow in a series of subbasins when given precipitation and temperature data, can be used to both explain the past and predict the future. Scientists can use streamflow models to better understand how geologic structures formed or how a species may have interacted with ancient waterways throughout the course of a typical year. Those same scientists can use hydrologic models to predict how streamflow will react to climate change. The calibration of hydrologic models isn’t just useful to scientists, accurate streamflow data is also advantageous for farmers and recreationalists. Accurate streamflow estimates are a boon for farmers who will want to utilize water from nearby streams for irrigation, while floaters or fishermen will use streamflow information to determine if it is safe to have fun outdoors.

Rainfall-runoff models can often be compared with observed data. This data is typically gathered by sensors set up by organizations like the USGS that record daily streamflow levels. Like most observed datasets, observed streamflow data is prone to a margin of error and seasonal records are often incomplete. As a result, much research has gone into the calibration of hydrologic models using observed streamflow datasets. Kalman filters, a sequential data-assimilation algorithm, are one method of doing this.

A Kalman filter weights a model’s output against corresponding observations and corrects the model’s output so the final output is more like the observations. In 2005, Moradkhani et al. combined two advanced types of Kalman filters, the Dual State Kalman filter and the Ensemble Kalman filter, to create a Dual State Ensemble Kalman Filter that operated on a rainfall-runoff model. Dual State filters, coined around 1976 by Todini et al., are useful because they correct a series of model parameters in addition to the model output. Ensemble Kalman Filters, introduced by G. Evensen in 1994, both allow Kalman filters to operate on non-linear models and allow for the calculation of an ensemble covariance matrix, a process that can speed up the filter when high-dimensional states are being corrected.

My research expands upon Moradkhani et al. by attempting to calibrate a unique rainfall-runoff model developed by University of Montana professor Marko Maneta. His model is unique for two reasons: 1) In addition to the rainfall-runoff equations this model utilizes a Muskingum-Cunge routing component, a component that accounts for a variety of factors including flood plains and 2) This model utilizes high-dimensional spatially distributed catchments, each containing a series of empirical parameters.

Since this hydrologic model contains spatially distributed parameters, it is reasonable to hypothesize that some parameters are hierarchically related – that is, some parameters will be related to each other because of proximity or shared geological characteristics. To account for this a component of the Dual Ensemble Kalman Filter called the ‘kernel smoothing algorithm’ has been modified in such a way that it treats parameters as hierarchically related.

To connect each parameter to a hierarchical group the 330 subbasins in Prof. Maneta’s model have been sorted into 3 distinct groups. These groups correspond to large hydrologic drainage areas called HUC-4 watershed sub-regions. Hopefully, these innovations will lead to a new method for filtering not just hydrologic models, but hierarchically structured models in general.

My research addresses two major questions. Firstly, I want to know whether the ‘Hierarchical Dual State Ensemble Kalman Filter’ technique that we have created through the modification of the kernel-smoothing component can accurately estimate the parameters for the rainfall-runoff model. Secondly, I want to know how the accuracy of this new method compares to the accuracy of the standard Dual State Ensemble Kalman Filter running on the same rainfall-runoff model. These questions will help determine the viability of our new filtering method.