Developing a new data assimilation technique based on polynomial chaos expansion theory for hydrologic prediction

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Data assimilation (DA) has become popular in the hydrologic prediction, focusing on the improvement of accuracy and efficiency. In this study, we proposed a new surrogate filter using polynomial chaos expansion (PCE), which aims not only to ensure accuracy in streamflow forecasting by updating the model states and parameters but also to significantly improve the computational efficiency. We presented here eight different approaches which can be classified into two main categories: either time-invariant filters (surrogate filters needed to be built once and can be applied to multiple forecast periods) or time-variant filters (surrogate filters needed to be rebuilt at each forecasting time). Besides, an optimal framework that is necessary during the construction of surrogate filters was proposed to optimize the hyper-parameters of PCE with appropriate criteria, thereby increasing the efficiency in building a surrogate filter and avoiding the over-fitting phenomenon of PCE. These approaches proposed were verified with both single and dual ensemble Kalman filters (EnKFs). Applicable results of surrogate filters with both synthetic and real data experiments illustrate that (1) most of these surrogate filters can account for different sources of uncertainty like original EnKF; (2) All surrogate filters provide relatively good forecasting results with small lead times. However, time-variant filters are capable of providing predictive results as well as providing more appropriate posterior parameters than time-invariant filters; therefore, with long lead times, the forecast of time-invariant filters is less accurate than other filters; (3) surrogate filters have significantly increased performance compared to original filters at a faster rate of up to 500 times, significant in forecasting, mainly when it is applied to large domain or complex models. Generally, results from both real and synthetic studies suggest that the proposed filter guarantees the effectiveness and usefulness with a significant improvement in the computational performance for hydrologic prediction.

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