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Comparison Of Ensemble Kalman Filtering And Particle Filtering On Short-Term Streamflow Forecasting Using A Distributed Hydrologic Model

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COMPARISON OF ENSEMBLE KALMAN FILTERING AND PARTICLE FILTERING ON SHORT-TERM STREAMFLOW FORECASTING USING A DISTRIBUTED HYDROLOGIC MODEL

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Floods are the most common and widespread disasters in the world and are responsible for a greater number of damaging events than any other type of natural event. However, due to various uncertainties that originate from simulation models, observations, and forcing data, it is still insufficient to obtain accurate flood forecasting results with the required lead times. Recently, ensemble forecasting techniques based on data assimilation (DA) have become increasingly popular, due to their potential ability to explicitly handle the various sources of uncertainty in operational hydrological models. Difficulty lies in DA for flood forecasting because nonlinearity increases sharply during flood events and the probability of streamflow cannot be characterized by the Gaussian assumption. Particle filtering (PF), also known as sequential Monte Carlo (SMC) methods, is a Bayesian learning process in which the propagation of all uncertainties is conducted by a suitable selection of randomly generated particles without any assumptions about the nature of the distributions. In this paper, the performance of ensemble Kalman filtering (EnKF) and PF is assessed for short-term streamflow forecasting with a distributed hydrologic model, namely, the water and energy transfer processes (WEP) model. To mitigate the drawbacks of conventional filters, the ensemble square root filter (EnSRF) and the regularized particle filter (RPF) are implemented. For both the EnSRF and the RPF, sequential data assimilation is performed within a lag-time window to consider the response times of internal hydrologic processes. The proposed methods are applied to two catchments in Japan and Korea to assess their performance. The discussion will be focused on how non-Gaussian and non-linear property of floods affects updating results by two DA methods.

MATERIALS AND PRELIMINARY RESULTS

EnKF is a suboptimal estimator, where the error statistics are predicted using Monte Carlo methods. EnKF uses an ensemble of forecasts to estimate background error covariances. Despite wide-spread applications, there are difficulties remaining in EnKF from the fact that the posterior probability density of hydrologic states in a model is often non-Gaussian and cannot be adequately characterized by the first two moments. Furthermore, as EnKF actively updates states, it does not explicitly comply with the principle of conservation of mass. PF is a set of simulation-based methods that provide a flexible approach to computing posterior distributions without using any assumption about the nature of the distributions. Unlike Kalman filter-based methods, PF performs updating on particle weights instead of state variables, which has the advantage of reducing numerical instability, especially in physically based or process-based models. In addition, PF is applicable to non-Gaussian state-space models (Noh *et al.* [1], [2]).

The applied hydrologic model is the WEP model, which was developed for simulating spatially variable water and energy processes in catchments with complex land covers. The spatial calculation unit of the WEP model is a square or rectangular grid. Runoff routing on slopes and in rivers is conducted by applying a one-dimensional kinematic wave approach from upstream to downstream.

We implement two sequential data assimilation methods, the EnSRF and the RPF, for hindcasting of streamflow using the WEP model. Simulations are conducted for two small catchments in Japan and Korea to demonstrate the applicability of proposed methods for short-term streamflow forecasting. Fig. 1 shows Nash-Sutcliffe efficiency for varying lag-time windows and lead times in the EnSRF and the RPF. Updated ensembles via the EnSRF and the RPF produced improved streamflow predictions for lead times of up to 15 and 20 hours, respectively. The lag-time window contributed to improving performance of the EnSRF and the RPF, and the RPF yielded predictions equal to or better than those of the EnSRF in accuracy. In the case of the EnSRF, a decrease in model performance was observed for both catchments when the lead times were short (< 4 hours).

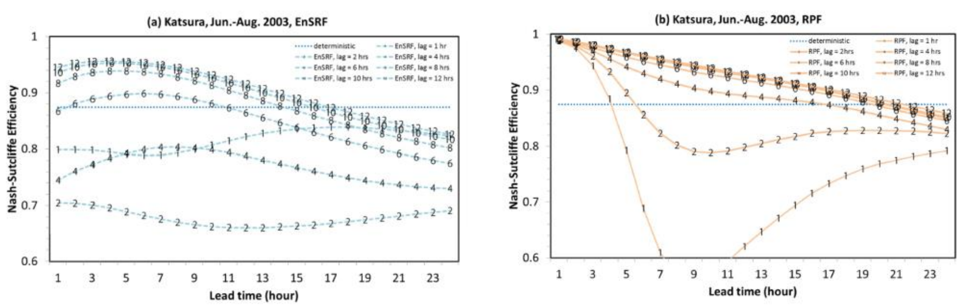

Figure 1. Comparison of simulation accuracy for varying lag-time windows and lead times.

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REFERENCES

[1] Noh, S. J., Tachikawa, Y., Shiiba, M., and Kim, S., "Applying sequential Monte Carlo methods into a distributed hydrologic model: lagged particle filtering approach with regularization", *Hydrology and Earth System Sciences*, Vol. 15, (2011), pp. 3237-3251.

[2] Noh, S. J., Tachikawa, Y., Shiiba, M., and Kim, S., "Ensemble Kalman Filtering and particle filtering in a lag-time window for short-term streamflow forecasting with a distributed hydrologic model", *J. Hydrol. Eng*., Vo. 18, (2013), pp. 1684–1696.