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Improved Assimilation of Streamflow and Satellite Soil Moisture with the Evolutionary Particle Filter and Geostatistical Modeling

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Assimilation of satellite soil moisture and streamflow data into hydrologic models using has received increasing attention over the past few years. Currently, these observations are increasingly used to improve the model streamflow and soil moisture predictions. However, the performance of this land data assimilation (DA) system still suffers from two limitations: 1) satellite data scarcity and quality; and 2) particle weight degeneration. In order to overcome these two limitations, we propose two possible solutions in this study. First, the general Gaussian geostatistical approach is proposed to overcome the limitation in the space/time resolution of satellite soil moisture products thus improving their accuracy at uncovered/biased grid cells. Secondly, an evolutionary PF approach based on Genetic Algorithm (GA) and Markov Chain Monte Carlo (MCMC), the so-called EPF-MCMC, is developed to further reduce weight degeneration and improve the robustness of the land DA system.
This study provides a detailed analysis of the joint and separate assimilation of streamflow and satellite soil moisture into a distributed Sacramento Soil Moisture Accounting (SAC-SMA) model, with the use of recently developed EPF-MCMC and the general Gaussian geostatistical approach. Performance is assessed over several basins in the USA selected from Model Parameter Estimation Experiment (MOPEX) and located in different climate regions. The results indicate that: 1) the general Gaussian approach can predict the soil moisture at uncovered grid cells within the expected satellite data quality threshold; 2) assimilation of satellite soil moisture inferred from the general Gaussian model can significantly improve the soil moisture predictions; and 3) in terms of both deterministic and probabilistic measures, the EPF-MCMC can achieve better streamflow predictions. These results recommend that the geostatistical model is a helpful tool to aid the remote sensing technique and the EPF-MCMC is a reliable and effective DA approach in hydrologic applications.