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Rainfall recharge estimation incorporating uncertainty based on nonlinear Monte-Carlo filtering technique

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The estimation of rainfall recharge to groundwater is crucial for the sustainable management of groundwater systems. Typically, soil water balance models are used to calculate rainfall recharge. In a soil water balance model, actual evapotranspiration (AET) is assumed to be a function of potential evapotranspiration (PET) and soil moisture. AET is reduced as soil water storage declines. In practice, the value of AET is difficult to observe and the estimate of it may be affected by noise including uncertainty in PET. Therefore, improvements to the accuracy of rainfall recharge calculations with soil water balance models can be obtained with better estimates of AET and by ensuring a reliable quantification of the estimation uncertainty.

To improve the estimation of rainfall recharge to groundwater, a nonlinear Monte-Carlo filtering technique is developed by formulating a soil water balance model in a dynamic Bayesian state-space model formulation. In this work, the actual evapotranspiration is treated as the unknown dynamic state variable in the dynamic state-space model formulation. The nonlinear Monte-Carlo filtering technique is based on recursively constructing the posterior probability density (distribution) of the state variable of AET, with respect to measured rainfall recharge, through a random trajectory of the state by entities called 'particles'. A weight, which is the probability of the trajectory of the state, is assigned to each particle by a Bayesian correction term based on rainfall recharge measurement. The technique evolves and adapts the swarm of particles to measured rainfall recharge data from lysimeters. Measured daily rainfall recharge data at four lysimeter installations over the period 1999 to 2010 in the Canterbury Plains of South Island, New Zealand are used to demonstrate the usefulness of the developed nonlinear Monte-Carlo filtering technique for the estimation of rainfall recharge. The results suggest that the performance of the technique is better than that of a soil water balance model optimised by the traditional nonlinear gradient-decent methods in terms of root mean square error (RMSE) and cumulative sums of rainfall recharge.