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Nonstationary spectral methods to delineate stochastic well capture zones in mildly nonstationary groundwater flow systems

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This study presents an approximate spectral method (ASM) to delineate well capture zones in mildly nonstationary groundwater systems. Taking advantages of spectral theories in solving unmodeled small-scale variability in hydraulic conductivity (K), the proposed spectral method can efficiently estimate flow uncertainties. Such velocity uncertainties associated with the particle backward tracking algorithm and the concept of direct propagation of uncertainties of particle tracks can delineate stochastic well capture zones for groundwater systems with practical complexity and scales. In this study the developed ASM is assessed to quantify the accuracy of delineated well capture zones under a variety of conditions, including bounded flow domains, multiple wells flow systems, multiple hydraulic conductivity scales, and nonstationary flows caused by complex sources and sinks in the modeling areas. The ASM solutions are systematically compared with the corresponding numerical solutions of nonstationary spectral method (NSM) and Monte Carlo simulation (MCS). Simulation results reveal that the proposed ASM is computationally efficient and the solution of velocity variances agrees well with the corresponding numerical solutions of NSM and MCS. Furthermore, the developed ASM can delineate accurately the mean and variance dynamics of capture zones in complex large-scale groundwater flow systems, where the small-scale variation of hydraulic conductivity is considered to be mildly nonstationary.