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Anomalous Diffusions of Suspended Sediment Transport by Two-particle Stochastic Diffusion Particle Tracking Model

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Movement of suspended sediment particles is regarded as a stochastic process due to highly uncertain behaviors of particles under the influence of flow velocity and the turbulent effect in the open channel flow. In the study, a-state-of-the-art two particle stochastic diffusion particle tracking model (two-particle SD-PTM) is proposed. Modified from the stochastic diffusion particle tracking model (SD-PTM), the two-particle SD-PTM takes the particle correlation into consideration while modeling the random behaviors of the suspended sediment particles. Affected by the large eddy turbulence, the two particles (paired particles) have similar motion when they are in the vicinity of each other. On the other hand, paired particles move independently when they are far away from each other. The proposed two particle SD-PTM model are validated against concentration data from experiments. Numerical experiments on the stability of the simulations are conducted and discussed.

In the study, suspended sediment particle transport is hypothesized to possess the Markovian property and to follow the Fickian law. While the Markovian property is validated, showing that the suspended sediment transport is memoryless, the Fickian hypothesis is falsified by the observed anomalous diffusions based on the simulation results of ensemble variances of particle displacements. In the streamwise direction, suspended particle motions change from normal diffusion to superdiffusion. Transitions from minor superdiffusion to subdiffusion of particle motions are discovered in the vertical direction. The deposition and resuspension of particle motions might be the primary contributor leading to the particle anomalous diffusions. Influence of particle correlation is shown in comparisons of the one-particle SD-PTM and two-particle SD-PTM.

Keywords: stochastic model; particle tracking model; stochastic differential equations; stochastic sediment transport; two-particle model; Markovian property; anomalous diffusion