Modeling of Lagrangian particles in turbulence boundary layer considering attached eddies: particle trajectories and concentration profiles

Yu-Ying Huang and Christina W. Tsai
Department of Civil Engineering, National Taiwan University, Taipei, Taiwan

Sediment particles in flow not only follow the mean drift, but also diffuse randomly due to turbulence. Owing to this property, Lagrangian particle trajectory is regarded as a stochastic process in this study. The proposed model based on Lagrangian methods will combine physical mechanisms and stochastic methods to simulate the particle motion, and uses the Brownian motion to describe the diffusion affected by turbulence. In turbulence boundary layer, there are eddies with different length and velocity scales. Eddies affect the motion of a particle, like the occurrences of ejection and sweep events. Among others, those extended to the wall, named attached eddies, are primarily responsible for most of the turbulent kinetic energy and Reynolds shear stresses. Perry & Marušić (1995) further divided the attached eddies into two types, those directly attached to the wall are called Type-A eddies while others not directly attached to the wall in the wake region are called Type-B eddies. The scales of Type-B eddies are affected by the distance away from the wall. Therefore, this study will combine the above-mentioned theory and the stochastic diffusion particle tracking model (SD-PTM) to simulate the Lagrangian sediment particles in turbulence boundary layer considering the effects of attached eddies.

The SD-PTM which has been built on the Lagrangian scheme and derived from the Langevin equation has two main parts – the mean drift term and the turbulence term. The proposed model will separate the turbulence term into the effects by Type-A eddies and the effects by Type-B eddies, respectively. In the simulation results of sediment concentration in Tsai & Huang (2019), it can be found that when only Type-A eddies are considered, there were some discrepancies except for the near wall region within about 20% of the thickness of turbulence boundary layer. Hence, after taking into account for the effects of Type-B eddies in the proposed model, it can be expected that accuracy of the simulation results of Lagrangian particle trajectories and sediment concentrations can be improved throughout the whole boundary layer.

Keywords: Lagrangian methods, stochastic particle tracking model, attached eddies, Brownian motion, particle trajectories