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臺灣大學應用力學研究所

演　講　公　告

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主 講 人：Prof. Tian-Jian Hsu
Donald C. Phillips Professor of Civil, Construction, and Environmental Engineering at the University of Delaware (UD)

講　　題：Large-eddy simulation of ripple evolution using a two-phase model and its preliminary application to benthic flux

摘　　要：　如附件

主 持 人：　周逸儒教授

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Large-eddy simulation of ripple evolution using a two-phase model and its preliminary application to benthic flux

Prof. Tian-Jian Hsu
Department of Civil, Construction, and Environmental Engineering
University of Delaware (UD), USA

Abstract

Bedforms are prominent small-scale morphological features dictating hydrodynamic dissipation and sediment transport in aquatic environments. In the sandy nearshore of medium to coarse sands, vortex ripples with a steepness larger than 0.1 are ubiquitous and the vortices generated due to boundary layer separation are regarded as the primary mechanism driving sediment transport. For fine to medium sand environments, ripple steepness is often smaller than 0.1. As the bedforms-induced vortices and boundary layer turbulence must co-exist, research gaps exist concerning the physical mechanism driving lower steepness ripples and more generally, the role of turbulent coherent structures on bedform evolutions. Here, we investigate the mechanism driving bedforms evolution from an initially flat bed, for fine-medium sand ripples in oscillatory flows. Due to much lower steepness, the ripple-induced vortices are much weaker, and we hypothesize that turbulent coherent structures play a crucial role in driving sediment transport to initiate small bed features. The Eulerian two-phase flow model, SedFoam, is utilized to perform 3D large-eddy simulation. The laboratory experiments of Perillo et al. (2014, Sedimentology) are modeled for medium sand ripple ($d_{50} = 0.25$ mm) at mobility number varied from 10 to 60. Through LES, the generation and evolution of energy-containing turbulent coherent structures are resolved, as well as the resulting sediment transport. Results demonstrate that the turbulent coherent structures, generated by shear flow in the turbulent boundary layer, are the dominant mechanism driving the initial formation of 3D small bed features, which eventually evolve into more organized symmetrical small ripples (SSR). The model can reproduce the expected ripple steepness provided that a simulation can be carried out sufficiently long to reach the equilibrium state. The model also captures the expected change from 2D to 3D ripples when the mobility number is increased. Preliminary analysis shows that the two-phase model produces the expected pore flow inside the ripple and benthic flux across the sediment-water interface driven by time-dependent dynamic pressure gradient over evolving ripples. This suggests that the Eulerian two-phase model for sediment transport can be extended into a holistic numerical framework to simulate solute, oxygen and nutrient exchange through the sediment-water interface.

Biography

Tian-Jian Hsu (Tom) is Donald C. Phillips Professor of Civil, Construction, and Environmental Engineering at the University of Delaware (UD). Since July 2020, he served as the Director of the Center for Applied Coastal Research. Hsu earned a bachelor degree in Ocean Engineering from National Taiwan University in 1994 and PhD degree in Civil Engineering from Cornell University in 2002. Before joining UD, he was a Postdoctoral Scholar and Assistant Scientists at Woods Hole Oceanographic Institution and an Assistant Professor of University of Florida. He received NSF Early Career Development (CAREER) Award in 2007. He was also the recipient of the 2021 Hans Albert Einstein Award (ASCE) for his research contribution in sediment transport. Hsu served as the Associate Editor of Journal of Geophysical Research: Oceans from 2011 to 2019. Currently, he served as the guest editor for a special issue of swash zone processes for the Coastal Engineering. In 2020, he served as guest editor for a special issue on two-phase modeling for sediment dynamics for the European Journal of Mechanics - B/Fluid. Between 2015 to 2019, he was elected as an executive committee member of Community Surface Dynamics and System (CSDMS) and the Chair of Cyberinformatics and Numerics Working group of CSDMS. Hsu’s main research covers numerical modeling/simulation of various sediment transport problems, including wave-driven sediment transport, flocculation of cohesive sediments and their interaction with spilt oil and organic matters. Hsu’s research team devoted major efforts to create open-source numerical modeling tools for nearshore processes and sediment transport in the OpenFOAM framework.