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Sand Waves in Environmental Flows: Insights gained by LES[1]

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In fluvial and coastal environments, sediment transport processes induced by near-bed coherent structures in the turbulent boundary layer developing over a mobile sediment bed result in the formation of dynamically rich sand waves, or bed forms, which grow and migrate continuously. Bed form migration alters streambed roughness and provides the primary mechanism for transporting large amounts of sediment through riverine systems impacting the morphology, streambank stability, and ecology of waterways. I will present recent computational advances, which have enabled coupled, hydro-morphodynamic large-eddy simulation (LES) of turbulent flow in mobile-bed open channels. Numerical simulations: 1) elucidate the role of near-bed sweeps in the turbulent boundary layer as the mechanism for initiating the instability of the initially flat sand bed; 2) show how near-bed processes give rise to aperiodic eruptions of suspended sediment at the free surface; and 3) clarify the mechanism via which sand waves migrate. Furthermore, in agreement with recent experimental observations, the computed spectra of the resolved velocity fluctuations above the bed exhibit a distinct spectral gap whose width increases with distance from the bed. The spectral gap delineates the spectrum of turbulence from that of slowly evolving coherent structures associated with sand wave migration. The talk will also present computational results demonstrating the feasibility of carrying out coupled, hydro-morphodynamic LES of large dunes migrating in meandering streams and rivers with embedded hydraulic structures and discuss future challenges and opportunities.

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