Apr 25, 2019

Settling of Cohesive Sediment: Particle-resolved Simulations

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ABSTRACT:

We develop a physical and computational model for performing fully coupled, grain-resolving Direct Numerical Simulations of cohesive sediment, based on the Immersed Boundary Method. The model distributes the cohesive forces over a thin shell surrounding each particle, thereby allowing for the spatial and temporal resolution of the cohesive forces during particle-particle interactions. We test and validate the cohesive force model for binary particle interactions in the Drafting-Kissing-Tumbling (DKT) configuration. Cohesive sediment grains can remain attached to each other during the tumbling phase following the initial collision, thereby giving rise to the formation of flocs. The DKT simulations demonstrate that cohesive particle pairs settle in a preferred orientation, with particles of very different sizes preferentially aligning themselves in the vertical direction, so that the smaller particle is drafted in the wake of the larger one. This preferred orientation of cohesive particle pairs is found to remain influential for much larger simulations of 1,261 polydisperse particles released from rest. These simulations reproduce several earlier experimental observations by other authors, such as the accelerated settling of sand and silt particles due to particle bonding, the stratification of cohesive sediment deposits, and the consolidation process of the deposit. This final phase also shows the build-up of cohesive and direct contact intergranular stresses. The simulations demonstrate that cohesive forces accelerate the overall settling process primarily because smaller grains attach to larger ones and settle in their wakes. An investigation of the energy budget shows that the work of the collision forces substantially modifies the relevant energy conversion processes.

BIOGRAPHY:

Professor Meiburg's research interests lie in the general area of fluid dynamics and transport phenomena. His group primarily employs the tools of computational fluid dynamics (CFD), in particular highly resolved direct numerical simulations, in order to obtain insight into the physical mechanisms that govern the spatio-temporal evolution of a wide variety of geophysical, porous media and multiphase flow fields. Occasionally, his group extends their analyses to address issues of linear stability as well. Frequently, they collaborate closely with corresponding experimental investigations. Some current interests focus on gravity and turbidity currents, Hele-Shaw displacements, double-diffusive phenomena in particle laden flows, and internal bores.