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A Three-dimensional Two-phase Mixture Model for Sediment Transport

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Suspended load often constitutes a large portion of the total load in a fluvial river. In classical fluvial numeric models, flows carrying suspended sediment are usually modeled by the Reynolds averaged equations directly borrowed from the classical fluid dynamics for single-phase flows with an advection-diffusion equation and single-phase turbulence model is adopted to close the equations. Due to the omission of the effect of the sediment on fluid, results from the classical models can deviate significantly from experimental and field observations. In this paper, we develop a three-dimensional numerical model based on two-phase mixture theory to study the sediment-laden flows. The two-phase mixture equations are closed by a two-phase mixture turbulence model derived from two-fluid turbulence model. The two-phase mixture model therefore inherits the essential capabilities of two-fluid models in considering inter-phase interaction, but without solving the full set of governing equations for the two-fluid models. Two-phase mixture equations have similar form to the governing equations for classical fluvial hydraulics, thus allowing us to embed the two-phase mixture model into SCHISM, a 3D unstructured-grid model for oceans, estuaries and rivers. We verify the new model with a set of experiments , and the results show that the new model is valid for sediment-laden flows covering a wide range of particle diameters and concentrations. We also apply the new model to the study of representative flood events in the Lower Yellow River (LYR), and investigate sediment distributions, velocity profiles, circulation flows in river bends, flood propagation and erosion and deposition patterns. The computed water surface elevation, cross-sectional bathymetry and sediment concentration show good agreement with the measured data.