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LARGE EDDY SIMULATION OF TWO-WAY COUPLING SEDIMENT TRANSPORT

Maryam Dallali, Vincenzo Armenio
Dept. Eng. and Architecture University of Trieste, Italy.
e-mail: maryam.dallali@phd.units.it, armenio@dicar.units.it

Transport of suspended sediments in turbulent channel flow is usually simulated in passive form in which the feedback effect of sediment re-suspension on near-wall momentum transport is negligible. The purpose of present study is to quantify the above mentioned effect with the aim of gaining better description of sediment-turbulence interaction. We consider both one-way coupling and two-way coupling, meaning that sediment concentration affects momentum transport through gravity term.

Large Eddy Simulations (LES) of non-cohesive sediment transport in open channel flow is carried out.

The simulation is based on the Euler-Euler approach in which incompressible 3D Navier-Stokes equations under the Boussinesq approximation for buoyancy effects are employed for flow field. Particle transport in suspension is computed by advection-diffusion equation. The considered model for fluid-particles interface relies on pick-up function given by van Rijn (J. Hydraulic, 1984). The feedback effect on momentum transfer is accounted for through an increased mixture density in the vertical momentum equations.

We apply the Shield criterion for sediments movement based on the critical shear stress value as a function of particle Reynolds number. The dimensionless shear stress is defined by $\theta=\tau/(g' d)$ where the modified gravity is $g'=g(\rho_s-\rho)/\rho$. Once the instantaneous wall shear stress exceeds the critical shear stress the sediments are entrained and transported through flow field. In the present work we use wall-resolving LES to make simulations free of model errors at interface, at $Re_\tau=600$ with $d^+=5$. The corresponding value for $\theta=1.7$ allows suspension and deposition of sediments inside the domain.

The simulations in this study are conducted in a periodic free-surface channel flow with dimension of 5δ in streamwise and 2.5δ in spanwise direction (where δ is channel height), using the subgrid-scale model of Armenio and Piomelli (Flow Turb & Comb, 2000). The maximum dimensionless velocity in channel is $u^+=u/u_\tau=21$. Initial condition is zero sediment concentration over flow depth and boundary conditions for concentration are zero flux at free-surface and empirical flux by van Rijn at the bottom.

The concentration profile which shows the two-way coupling effect is presented in Fig.1. High flux of sediment concentration is observed in the viscous layer . The net sediment flux is composed of the turbulent part and diffusive part while the total value is equal to the erosion flux at the bottom boundary. Near the wall the turbulent term is negligible so the results show a high flux due to diffusivity. Apart the wall the turbulent part becomes significant and dominate the diffusivity term. The concentration of suspended sediments is damped down as a consequence of variation of vertical turbulent concentration flux associated to stable density stratification, coming from the two-way coupling effect. In the workshop we will discuss the two-way coupling effect on turbulence momentum and concentration vertical flux in details and also try to quantify the limiting value of concentration flux for the validity of one-way coupling assumption.

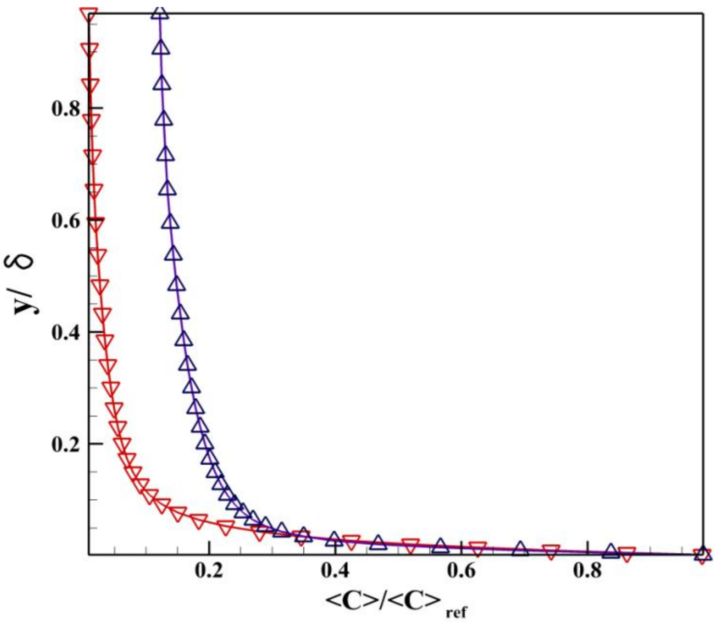

Fig.1 Vertical profile of averaged sediments concentration
One-way coupling simulation (delta); two-way coupling simulation (gradient).