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Sediment Transport Model with Linearized Free Surface Flow

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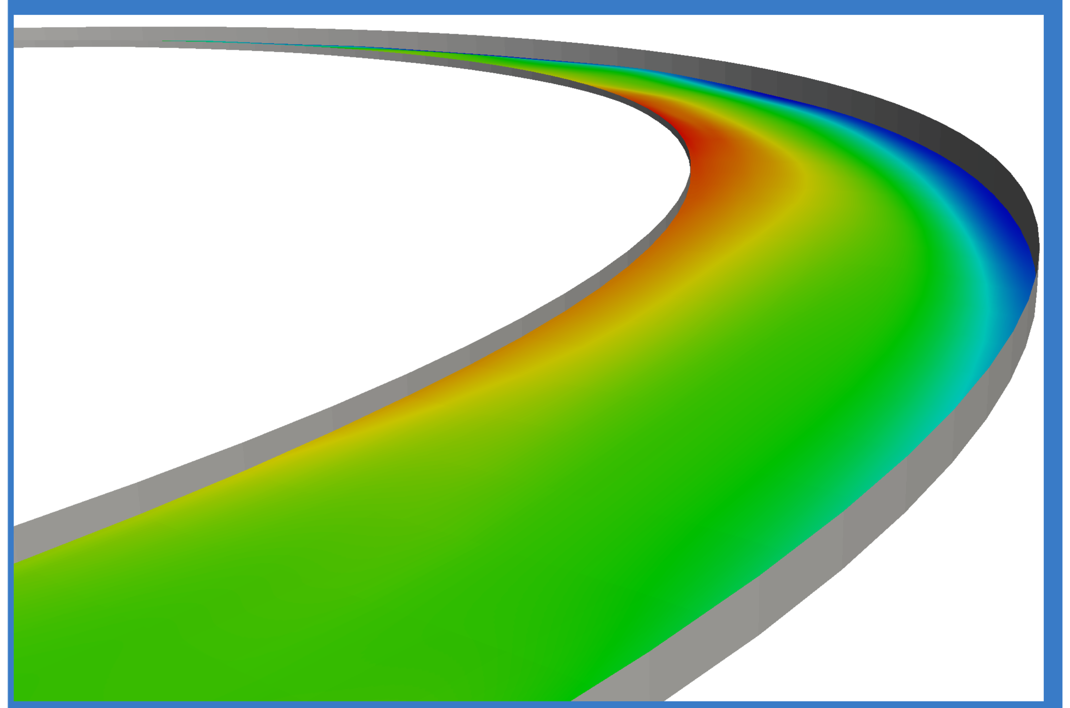


ABSTRACT

A 3D numerical model for simulation of free surface flow and sediment transport with sand bed deformation is presented in this study.

The fluid flow is calculated using the single-phase finite volume solver with linearized free surface boundary conditions based on the model by *Woolliscroft and Maki (2016)*, and implemented within the Naval Hydro pack in `foam-extend` by *Vukčević et al. (2017)*.

The sediment module incorporates suspended load and bed-load transport, with sand bed elevation evaluated using the Exner equation. Deformation of sand bed due to sediment deposition and scour is performed by the automatic mesh motion solver.

Comparison between the current and the two-phase flow model (*Škurić et al. 2015*) is presented on a 140° channel test cases with movable sand bed. Also, simulation results of a channel flow with cylindrical pier are presented.

Introduction

Simulation of flow and sediment transport in channels, rivers and shallow seas is a challenging, but important problem due to the impact of sediment erosion and deposition on river beds, sea beds and marine objects. Coupling between the fluid flow and sediment transport is required in order to achieve satisfying results. This includes accurate predictions of the flow and free surface waves, realistic shear stress values, correct suspended and bed-load sediment transport calculations with stable bed motion capabilities.

Mathematical Model

Suspended load transport of sediment is modelled by the convection-diffusion equation:

$$\frac{\partial c}{\partial t} + \nabla\!\cdot\!\left(\mathbf{U} - v_s \frac{\mathbf{g}}{|\mathbf{g}|}\right) c - \nabla\!\cdot\!(\nu_t \nabla c) = 0 \, ,$$

where c is the sediment concentration, v_s is the sediment fall velocity and ν_t is sediment diffusivity.

Bed-load transport is modelled by an explicit expression and discretised using the Finite Area Method (FAM):

$$\mathbf{q}_b = q_0 \frac{\tau_b}{|\tau_b|} - C|q_0| \cdot \nabla_s \eta \, ,$$

where τ_b is the bed shear stress vector, C is a constant (1.5 - 2.3), ∇_s is a surface gradient and η is bed elevation.

Bed elevation η is evaluated using the Exner equation (FAM):

$$\frac{\partial \eta}{\partial t} = \frac{1}{1-n}\left[\nabla\!\cdot\!\mathbf{q}_b + D - E\right] \, ,$$

where n is the bed porosity, E is the entrainment rate, D is the deposition rate.

Bed-load transport vector is directly coupled with the Exner equation.

Flow and Sediment Transport in a 140° Channel With a Mobile Bed

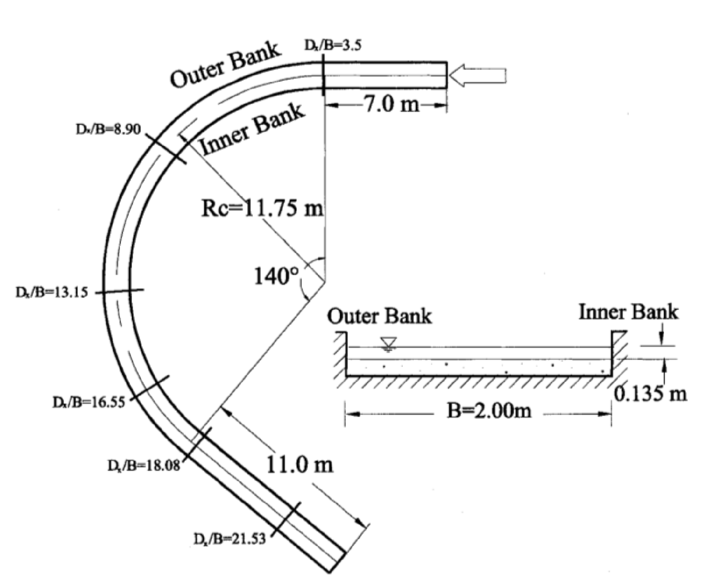
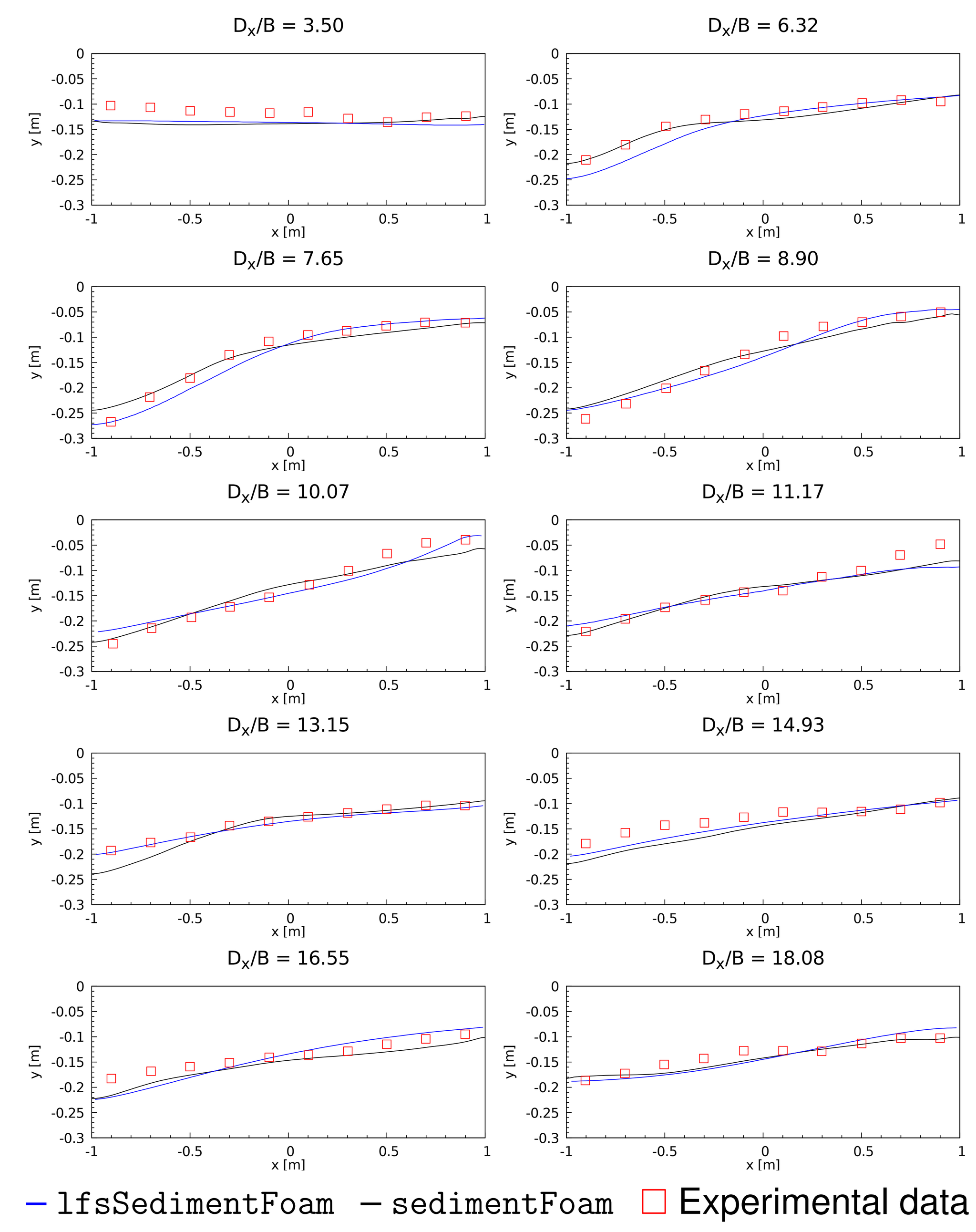


Figure 1: Experimental set-up of a 140° channel

Flow and sediment transport in a 140° channel with a 30 cm sand layer is presented. Bed depth measurements performed by *Olesen (1985)* are used for validation.

Figure 2: Comparison of water depth levels



Channel Flow with Circular Pier

Flow and sediment transport in a sand covered channel with circular pier is presented.

Figure 3: Sand height (depth) around pier at t = 20 min

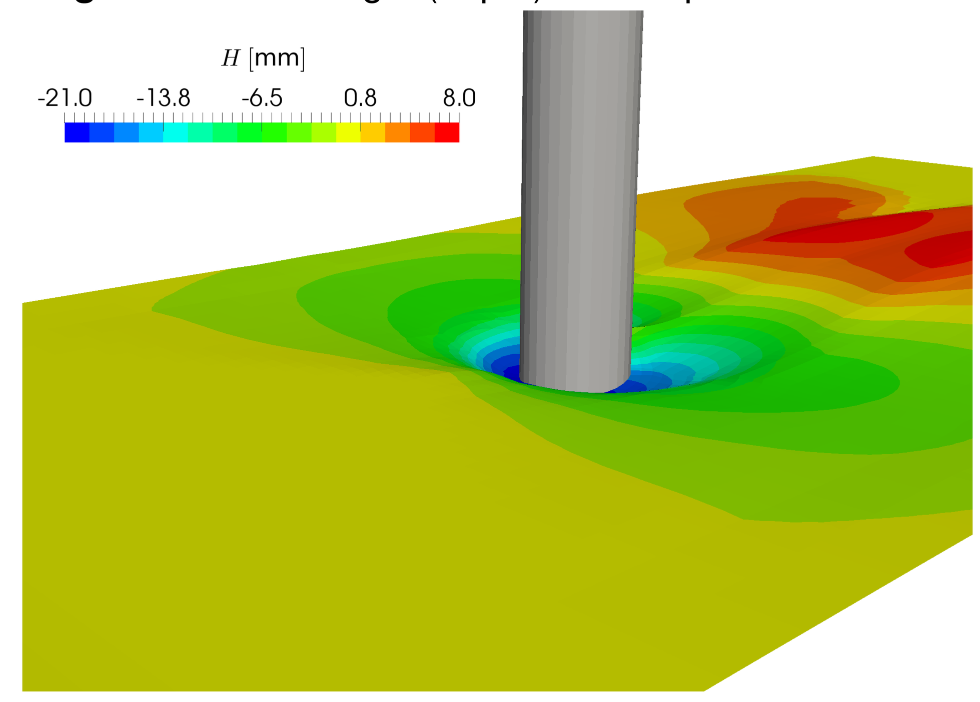
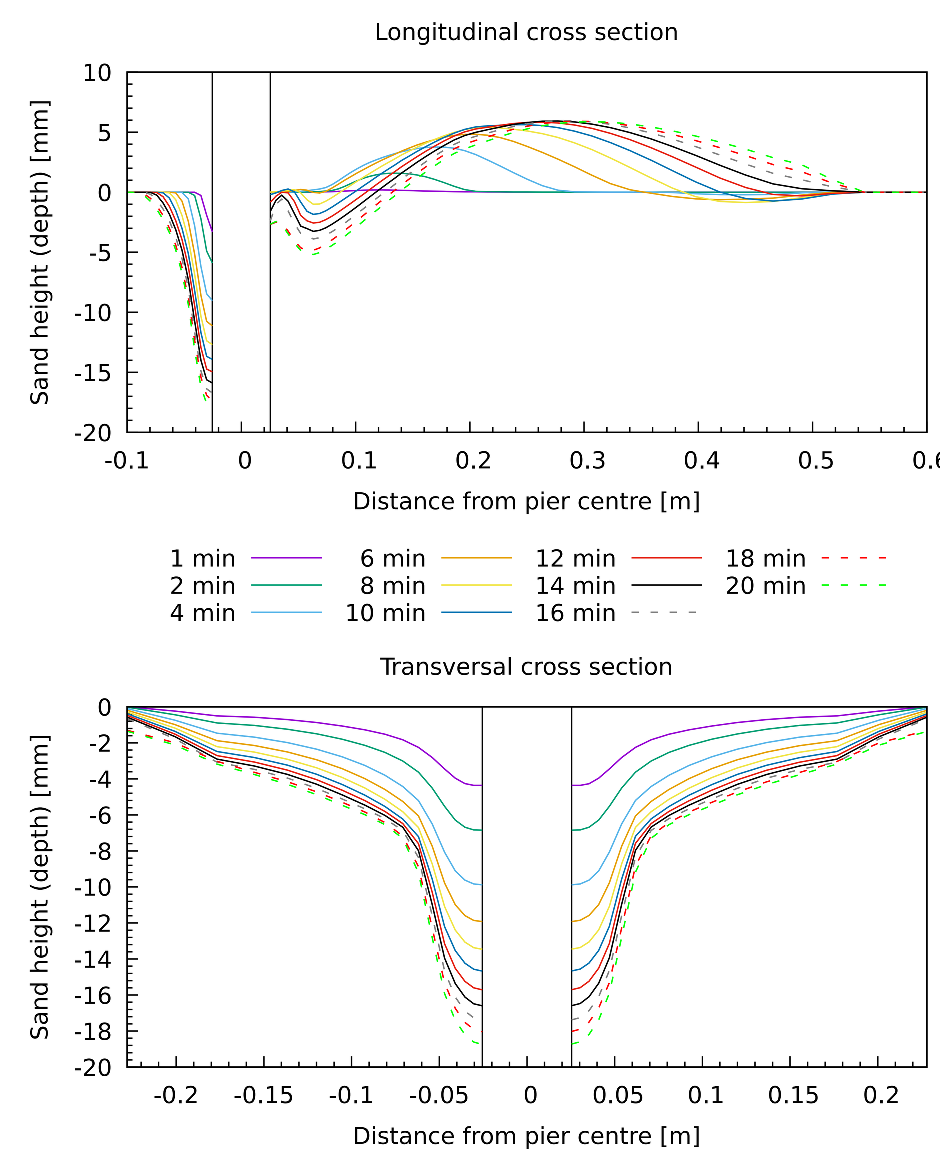


Figure 4: Sand height (depth) at transversal and longitudinal cross sections



Conclusion

Due to the free surface linearization (single-phase flow, no mesh above the free surface) simulation time is significantly reduced while preserving similar results.

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