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Numerical modelling of an unconfined ship propeller jet

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Aims:

- to explore the feasibility of the CFD in dealing with ship propeller jets;
- to visualize the flow fields generated by a rotating propeller and the scoured bed with a uniform flow;
- to increase the physical knowledge of the phenomena observed during laboratory experiments;
- to obtain useful information for optimization of blades, in terms of shape, dimensions and maneuvers (rpm, inclination), to reduce the scour phenomenon in harbors.

The propeller geometry used in the numerical simulations: the complex 3D shape of the blades was obtained using the Konica Minolta Vivid 910 3D laser scanner.

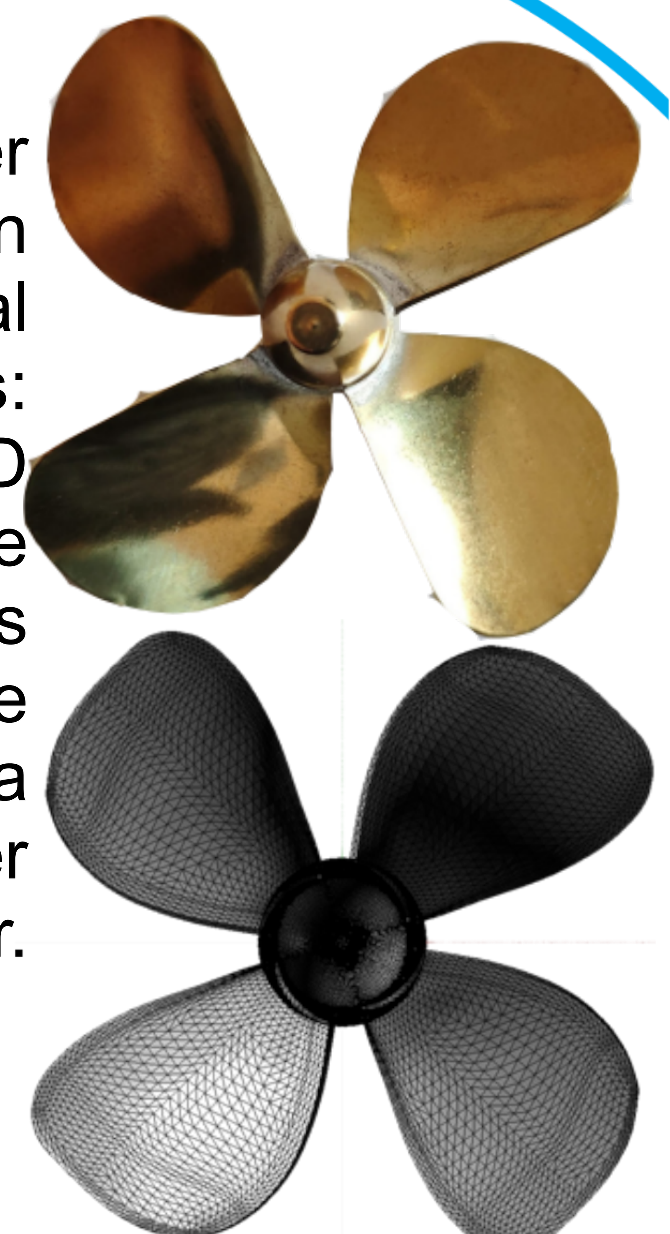

Fig. 1 - The four-blade propeller used in this study. Top: real; bottom: modeled

Numerical simulations were performed to analyze the flow behavior in the case of interactions between a propeller and a uniform flow acting on a deformed bed.

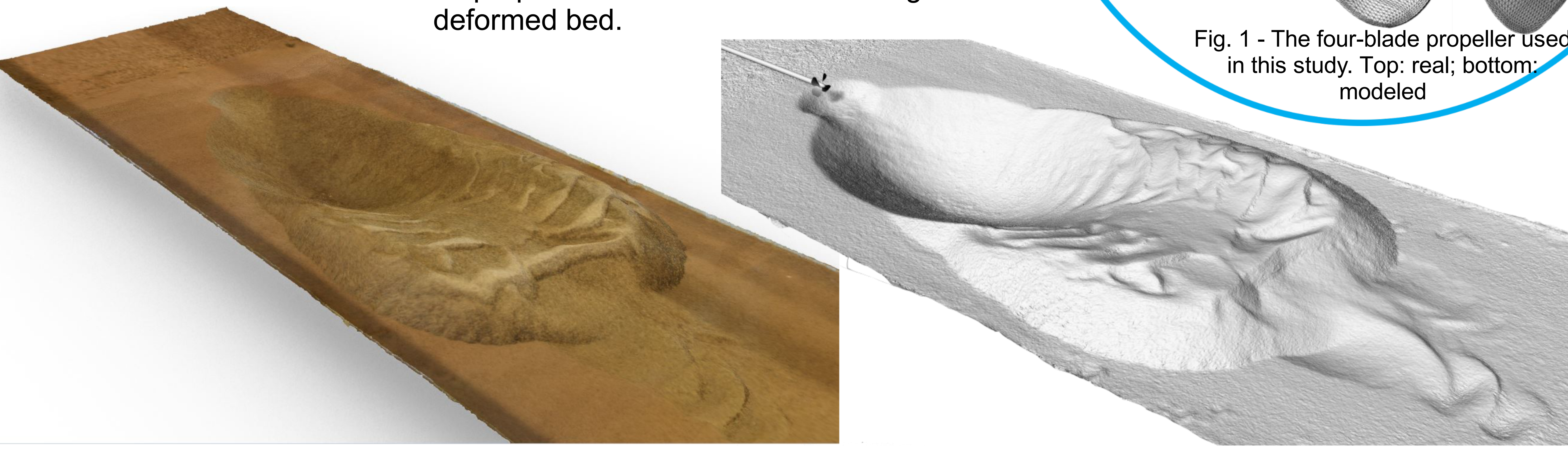

Fig. 2 - Computational domain reconstructed through the experimental survey performed with the photogrammetric technique

The flow field was simulated by solving the 3D RANS equations. The governing equations were solved numerically by means of the pimpleDyMFoam solver that is embedded in the OpenFoam toolbox. The pimpleDyMFoam is a transient solver for incompressible, turbulent flow of Newtonian fluids on a moving mesh.

To handle the mesh movements, the Arbitrary Mesh Interface (AMI) method was adopted.

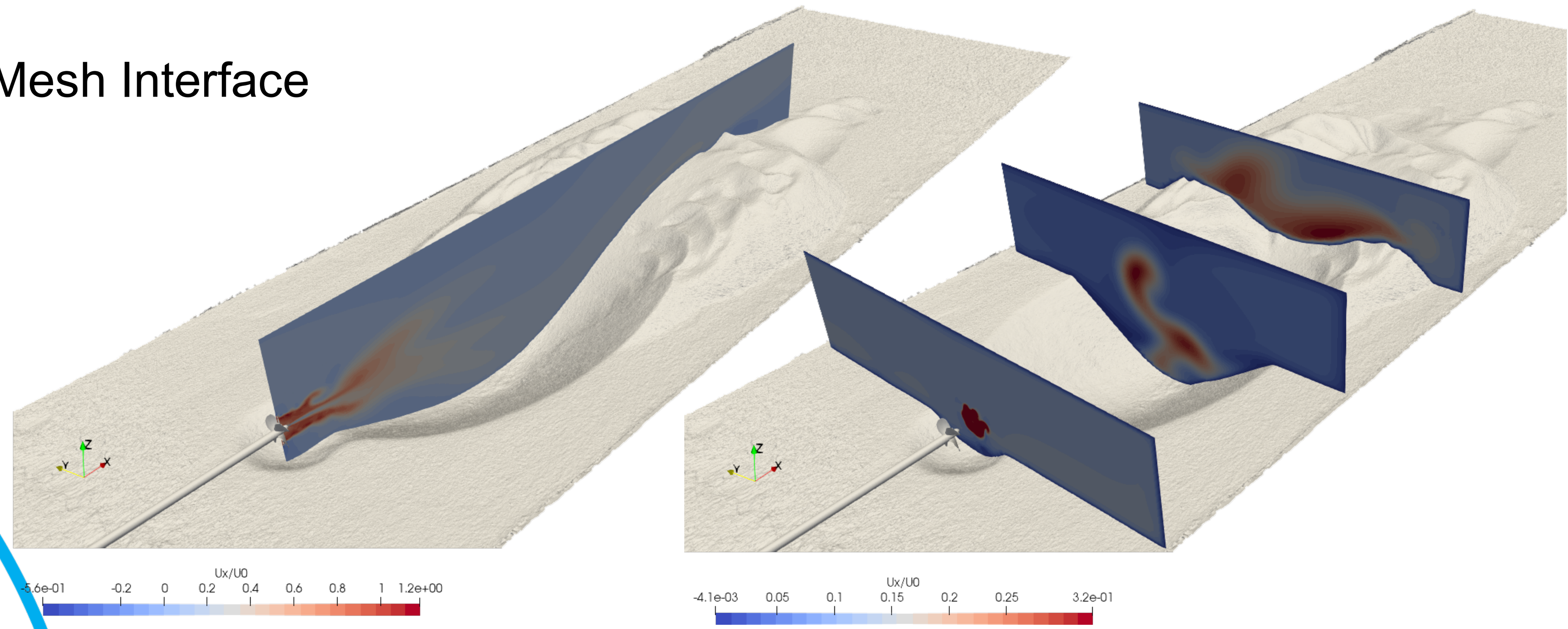

Fig. 4 - Numerical flow patterns in streamwise and spanwise directions.

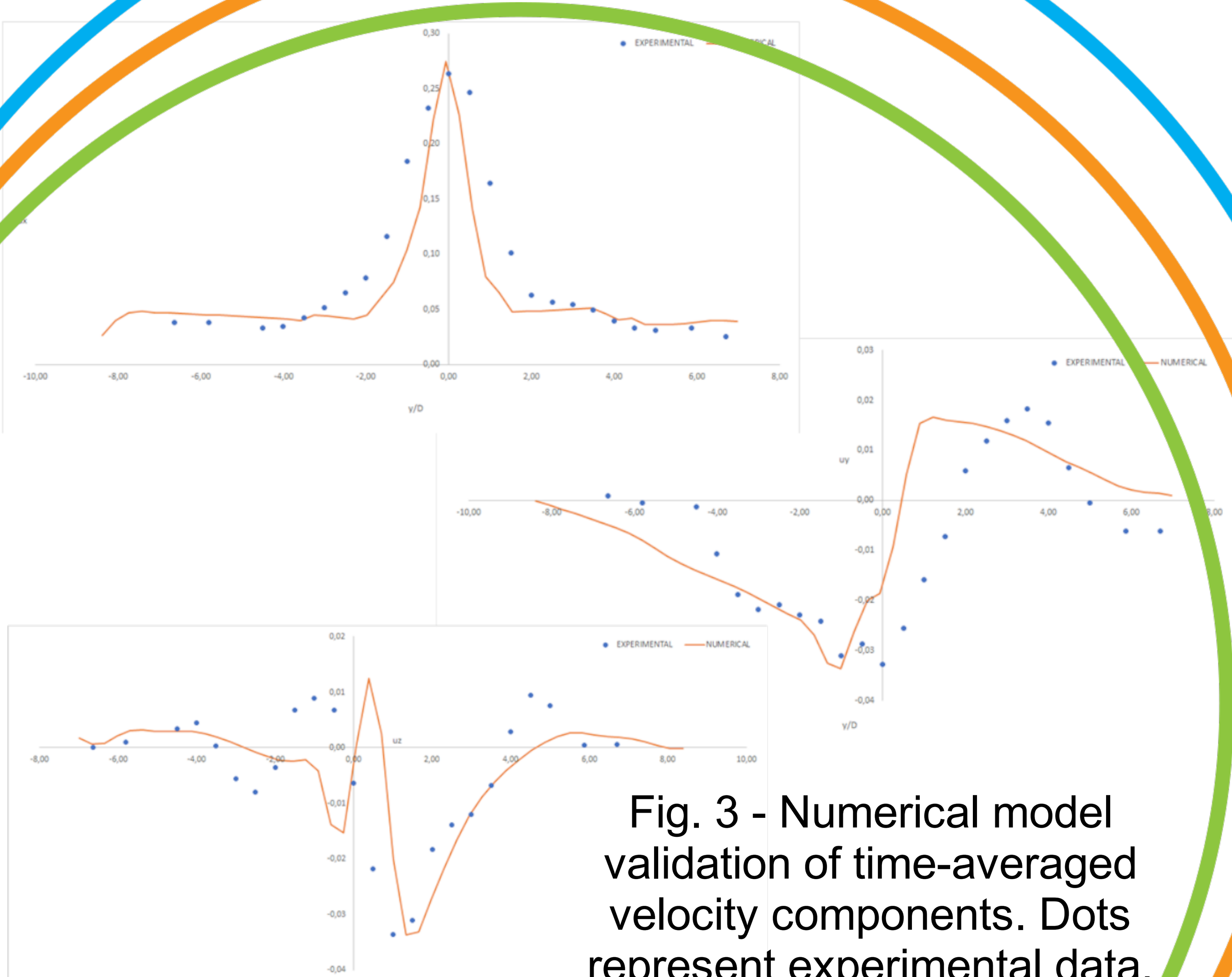

Fig. 3 - Numerical model validation of time-averaged velocity components. Dots represent experimental data, lines numerical results.

The 3D RANS equations with the k-ε model were successfully used and validated with the velocity signals measured using a four-beam down-looking Acoustic Doppler Velocimeter (ADV). A particular phenomenon observed as the Coanda effect, that causes the propeller jet to attach to the bed, could be observed only thanks to numerical simulations.