Hydrodynamic coupling of a SWE solver with a RANSE-CFD code

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ABSTRACT

RANSE-CFD based numerical models are a valuable tool to model complex three-dimensional hydrodynamic flow phenomena where pronounced vertical gradients influence the flow fields. However, computational demand is usually very high, omitting the simulation of hydro-/morphodynamics on a coastal scale. Thus, kilometer-scale domains to model coastal, estuarine, or inland waters ask for the use of more efficient model approaches, amongst which depth-averaged numerical models, such as shallow water equations (SWE) based models, are one suitable option. They can help to predict shallow-water wave deformation processes or large-scale free-surface flow phenomena, where the application of a RANSE-model would be too resource-demanding. Yet, SWE-models have several limitations, due to their inherent model assumptions. This restricts their application to mostly shallow or intermediate water-depths, and to cases where no flow stratification or pronounced vertical flow components exist [1].

The open-source modelling framework REEF3D provides hydrodynamic solvers for different applications, among them the high-fidelity RANSE-based model REEF3D::CFD [2], as well as the SWE-solver REEF3D::SFLOW [3], [4]. The implementation of a quadratic pressure approximation in REEF3D::SFLOW improves the model's dispersion characteristics, such that the application range is extended to increasingly deep water-depths compared to more traditional SWE models [5].

This work presents a novel one-way coupling interface between the two aforementioned solvers, that was developed to combine the advantages of both codes and to obtain an efficient tool, that allows to focus the computational effort in regions where accurate three-dimensional results for large scale hydrodynamic phenomena are needed. The coupled model enables starting RANSE simulations based on hydrodynamic boundary conditions obtained with the SWE-solver REEF3D::SFLOW. The information from the depth-averaged domain is stored, and afterwards imposed in the relaxation zone of the coupled CFD domain. Several verification and validation test cases concerning gravity wave propagation are presented, indicating a reliable and efficient performance of the newly developed coupling interface.

Numerous possible applications can benefit from the presented coupling approach, given the specific application range and additional modules of the respective codes. In coastal areas, incoming wind

waves can be calculated making use of REEF3D::SFLOW, while flow details around coastal structures can be specified with REEF3D::CFD. Several modules of REEF3D::CFD make it possible to simulate complex features such as porous [6] or floating objects [7], or to include morphodynamic activity in the simulation [8]. Another possible application is the simulation of long-period waves generated by ships navigating in confined waters. The wave generation and propagation can be modelled using REEF3D::SFLOW [9], while the complex effects imposed at the embankments can be modelled with REEF3D::CFD [10].

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