BOUSSINESQ MODELING OF SHIP-WAKES AND THEIR CONTRIBUTION TO COASTAL EROSION IN AN ADAPTIVE MESH REFINEMENT SYSTEM

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INTRODUCTION

Heavy ship traffic causes a growing concern with respect to public safety, potential damage of coastal structures, and corresponding environmental impacts. High-speed ship-generated wakes such as solitons, undular bores, and breaking bores behave differently compared to wind waves and have a great potential for damage in vulnerable areas such as low-energy coasts and wetlands.

In this study, we are developing a multi-grid model framework for the Fully Nonlinear Boussinesq Wave Model, FUNWAVE-TVD (Shi et al., 2012), for simulating ship-wakes in both the operational scale and refined process scales using full two-way coupling. Physical processes in areas of interest requiring higher model resolution, such as the ship-wake generation region, wave breaking in the near-field, and wave evolution with wave-structure interaction in the nearshore field, will be modeled in refined grids embedded in the operational-scale domain. A dynamically adaptive grid algorithm is implemented in order to track a vessel and calculate the physical processes precisely in the wave generation and breaking region in the vicinity of the vessel. Both pressure source and panel source methods for ship wave generation will be tested in the model framework. A concept of nesting layers based on the hierarchical basis, and an efficient parallelization method in the context of the full domain partition are utilized to allow the model to deal with a large-scale computation efficiently in a High Performance Computing (HPC) system.

STRUCTURED ADAPTIVE MESH REFINEMENT

The infrastructure of the multi-grid coupling system follows the strategy used in the recent development of multi-grid nesting ocean models such as the Regional Ocean Model Systems (ROMS) and Wave Watch III. The Structured Adaptive Mesh Refinement (SAMR) algorithm is used in the multi-level grid nesting system. Following the recent AMR version of FUNWAVE-TVD developed within the CACTUS framework (Chakrabarti, et al., 2017), we are developing a system-independent AMR model framework and focusing on the dynamically adaptive grid algorithm to facilitate modeling moving objects.

In a parallelized domain decomposition system, it is challenging to implement an efficient Message Passing Interface (MPI) scheme for communications between parent grids and child grids. The two-way coupling involves a large amount of interpolating and averaging processes between grids in each coupling time step. The use of global arrays may ease those calculations but would completely slow down the coupling system in terms of frequent gathering/distributing processes. In this study, we introduce a new communication algorithm which allows a direct data transfer between parent grids and child grids. The algorithm is implemented by mapping the parent grids and the child grids to each other with the MPI Cartesian topology. Model efficiency using the new communication algorithm will be examined against the global-array algorithm.

MODEL VALIDATION AND APPLICATION

Validation of the two-way nesting scheme is carried out using the ship-bore experiment by Gourlay (2001). The sediment and morphology modules in FUNWAVE-TVD are adapted into the multi-grid model framework for modeling coastal erosion induced by ship-wakes.

A field-scale simulation is conducted to test the model efficiency. The moving grid algorithm is used to calculate a fast vessel generated waves in a moving finer grid in order to increase the model accuracy in the near-field calculation. Figure 1 demonstrates a case in which ship-wakes are generated by two vessels moving with different speeds in the Galveston channel. Waves in the near-field of the vessels should be calculated in the nested finer grids as shown in the right panels. Note that the present result shown in the figure is for demonstration only. The detailed results will be presented in the conference.

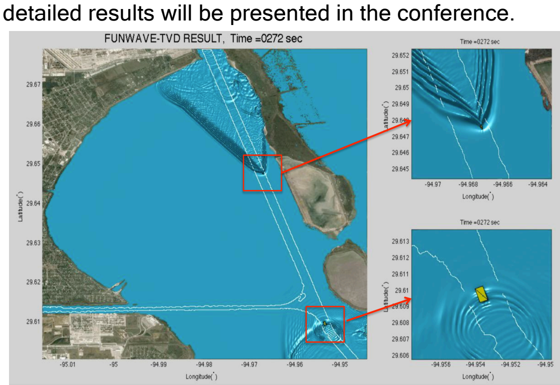

Figure 1 - Snapshot of ship-generated waves modeled at Galveston Navigation Channel. The blocks (red) represent the nested computational domains.

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