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W. Hou, S. Matt, and A. Kanaev

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14. ABSTRACT
The objective of this project is to further enhance the characterization of the Simulated Turbulence and Turbidity Environment (SiTTE). The numerical model emulates the Rayleigh•Benard laboratory tank at NRLSSC, which allows variation of turbulence intensity. This provides the framework for repeatable experimental conditions in a controlled setting. fu support of the 6.1 newstart project DOLFIN aimed at active boundary layer control for drag reduction, we implemented a numerical tank representation of a laminar to turbulent flow tank, a new acquisition at NRLSSC. To advance our understanding of Langmuir-type near surface coherent structures and associated turbulence, we refined experiments in the numerical tank emulating the SUSTAIN laboratory facility at the University of Miami with the goal of reproducing experimental conditions encountered during the laboratory work.

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SiTTE, turbulence intensity

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Author(s): W. Hou, S. Matt, and A. Kanaev
Affiliation(s): Naval Research Laboratory, Stennis Space Center, MS
CTA: CFD

Computer Resources: Cray XC40 [ARL, MD]

Research Objectives: The objective of this project is to further enhance the characterization of the Simulated Turbulence and Turbidity Environment (SiTTE). The numerical model emulates the Rayleigh-Bénard laboratory tank at NRLSSC, which allows variation of turbulence intensity. This provides the framework for repeatable experimental conditions in a controlled setting. In support of the 6.1 newstart project DOLFIN aimed at active boundary layer control for drag reduction, we implemented a numerical tank representation of a laminar to turbulent flow tank, a new acquisition at NRLSSC. To advance our understanding of Langmuir-type near surface coherent structures and associated turbulence, we refined experiments in the numerical tank emulating the SUSTAIN laboratory facility at the University of Miami with the goal of reproducing experimental conditions encountered during the laboratory work.

Methodology: Very high resolution simulations were required to continue to advance the characterization of the flow field in the laboratory tank at SiTTE, including boundary layer turbulence, and laminar to turbulent transition in a numerical flow tank. Experiments were implemented using the open source code OpenFOAM, in a large-eddy simulation formulation. To study Langmuir turbulence, the numerical model was refined using the Volume-of-Fluid multiphase approach and wave forcing was implemented using the wave2Foam and OpenFOAM-dev wave toolboxes available. Temperature was added as a tracer field.

Results: We further enhanced the characterization of the Simulated Turbulence and Turbidity Environment (SiTTE) laboratory tank and validated the results of our numerical tank with data from laboratory experiments using a Particle Image Velocimetry (PIV) system. Results from CFD simulations of the SiTTE tank provided the basis for optical modeling and the experimental description of beam wander due to optical turbulence. We performed large-eddy simulation of channel flow in a laminar to turbulent flow tank to explore the parameter space in terms of flow speeds and boundary layer instabilities. We refined multiphase simulations to study Langmuir Turbulence (Fig. 1). In addition to the successful implementation of wind and wave forcing to compare to laboratory experiments (Fig. 2), the model was modified to add the Craik-Leibovich vortex force terms to the model equations to test the performance of such parameterizations against the explicit simulation of the near-surface dynamics.

DoD Impact/Significance: SiTTE continues to be invaluable for the success of multi-divisional collaborative laboratory experiments with NRLDC, Univ. Nebraska-Lincoln, HBOI, and Dantec Dynamics Inc. SiTTE supports projects aimed at mitigating the effects of turbulence, as well as the 6.1 newstart DOLFIN and directly benefits research on optical communication, lidar sensing of turbulence (TURBOL), new fiber-optics sensor and compressive sensing imager development to study upper ocean processes. Advancing our understanding of the dynamics of boundary layer and air-sea interface dynamics, including Langmuir turbulence, is critical for the implementation of important near-surface processes in large-scale ocean circulation and forecast models.

- Domain: 18m by 6m by 2m
- Resolution:

Low Resolution case:
- $\Delta x = \Delta z = 6$ cm; $\Delta y = 2$ cm

~3 Million Nodes

High Resolution case:
- $\Delta x = \Delta z = \Delta y = 2$ cm

~27 Million Nodes

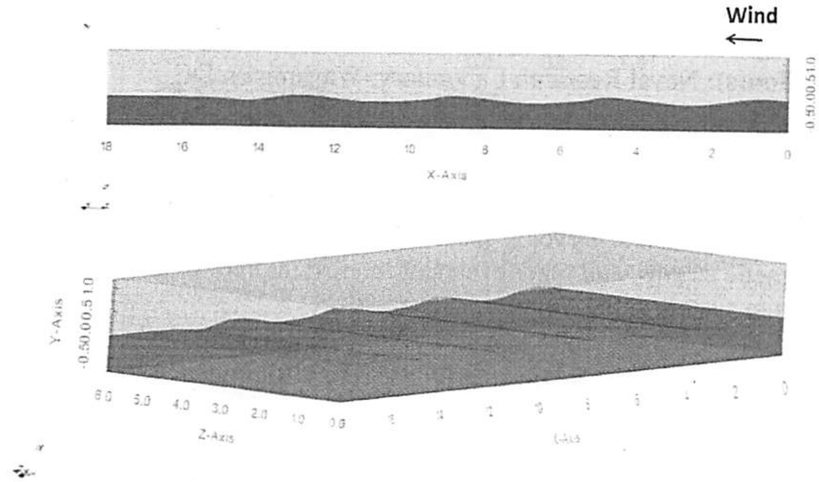

Figure 1. Numerical tank to emulate state-of-art SUSTAIN tank at the University of Miami. A computational fluid dynamics (CFD) model is implemented with a multiphase air-water setup in a Volume-of-Fluid (VOF) formulation.

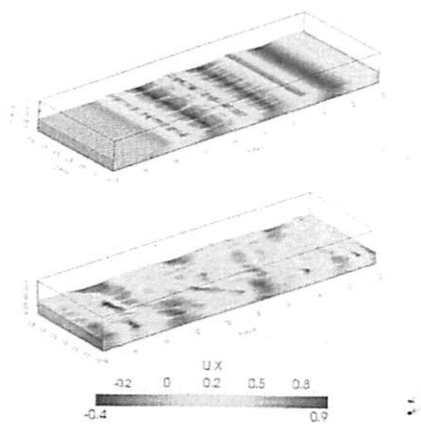

Figure 2. Top: Prescribed waves with added wind forcing (U = 2 m/s): Along-tank velocity (in m/s) at the water surface for high resolution case at steady state shows a pronounced multi-scale pattern of surface streaks consistent with Langmuir circulation. Bottom: Waves generated by wind forcing only: The surface streak pattern is comparable to the case shown above, but the wind forcing is much stronger (U = 10 m/s). Also note the more 3D nature of the wave field compared to the prescribed wave forcing.