A GPU-ACCELERATED MODELING OF SCALAR TRANSPORT BASED ON BOUSSINESQ-TYPE EQUATIONS

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ABSTRACT

This paper describes a two-dimensional scalar transport model solving advection-diffusion equation based on GPU-accelerated Boussinesq model called Celeris (Tavakkol and Lynett (2017)). Celeris is the firstlydeveloped Boussinesq-type model that is equipped with an interactive system between user and computing unit. Celeris provides greatly advantageous user-interface that one can change not only water level, topography but also model parameters while the simulation is running. In this study, an advection-diffusion equation for scalar transport was coupled with extended Boussinesg equations to simulate scalar transport in the nearshore. In the model, the advection-diffusion equation was solved by using a hybrid finite volume-finite difference scheme as adopted in Celeris. A second-order well-balanced positivity preserving central-upwind scheme was applied to the advective flux term (Kurganov and Petrova (2007)). In particular, the scheme was modified by adding an antidissipation function to minimize undesirable numerical dissipation (Liu (2019)). For the diffusion terms, secondorder central finite difference scheme was adopted. Besides, wave breaking model was considered to account for energy dissipation and turbulent mixing under breaking waves (Kennedy et at. (2000)). Finally, four benchmark tests were conducted to validate the coupled model. Two analytical cases were studied to examine the numerical diffusion. Moreover, two laboratory experiments were investigated. Firstly, a breaking solitary wave runup on a slope with a conical island was tested (Lynett et al. (2019)). The experiment observed dye performance while a solitary wave propagated, broke and eventually run-up over the shallow shelf with an island. The second test was associated with the development of vortex shedding in the wake behind the submerged island under the constant flow velocity field (Lloyd and Stansby (1997)). Dye transport by the vortex shedding was computed and compared experimental data. Throughout these benchmark tests, the computed results showed good agreement with analytical solutions and experimental data.

ACKNOWLEDGEMENT

This research was supported by the research project (2017R1D1A1B03031262) of Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education of the Republic of Korea.

REFERENCES

Tavakkol, S., & Lynett, P. (2017). Celeris: A GPU-accelerated open source software with a Boussinesq-type wave solver for real-time interactive simulation and visualization. Computer Physics Communications, 217,

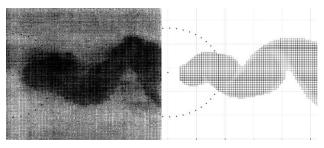


Figure 1 - Benchmark tests of Lloyd & Stansby (1997); (left) observed, (right) modeled.

117-127.

Kurganov, A., & Petrova, G. (2007). A second-order well-balanced positivity preserving central-upwind scheme for the Saint-Venant system. Communications in Mathematical Sciences, 5(1), 133-160.

Liu, X. (2019). A robust numerical model for shallow water governing solute transport with wet/dry interfaces. Computer Methods in Applied Mechanics and Engineering, 351, 85-108.

Kennedy, A. B., Chen, Q., Kirby, J. T., & Dalrymple, R. A. (2000). Boussinesq modeling of wave transformation, breaking, and runup. I: 1D. Journal of waterway, port, coastal, and ocean engineering, 126(1), 39-47.

Lloyd, P. M., & Stansby, P. K. (1997). Shallow-water flow around model conical islands of small side slope. II: Submerged. Journal of Hydraulic Engineering, 123(12), 1068-1077.

Lynett, P. J., & Swigler, D. T., & El Safty, H., & Montoya, L., & Keen, A. S., Son, S., & Higuera, H. (2019). Study of the Three-dimensional Hydrodynamics Associated with a Solitary Wave Traveling over an Alongshore-variable, Shallow Shelf. ASCE Journal of Waterway, Port, Coastal, and Ocean Engineering, 145(6), 04019024