AN EFFICIENT AND ROBUST GPGPU-BASED SHALLOW WATER MODEL

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INTRODUCTION

Phase-resolving nearshore wave models play an increasing role in coastal engineering design studies and academic research efforts. Most of these numerical models are built around Boussinesq-type and non-hydrostatic equations. Obviously, the underlying backbone of these equations is the set of the Nonlinear Shallow Water Equations (SWE)in the 2D horizontal plane. For most problems in the nearshore field, the hydrostatic pressure is dominant and the non-hydrostatic components, responsible for retaining some of the vertical flow structure, are rather small. In perspective of operational nearshore wave models, it is useful to start the effort of new model developments by focusing on the SWE sub-structure.

Despite significant improvements in CPU power in the past years, fast computations of nearshore waves over domains with millions of cells not only require expensive hardware (computer clusters) but also substantial amounts of time.

GPGPU computer codes based on computations on graphics cards are an attractive option to cut down on hardware expenses and to reduce computational time with the potential of utilizing these codes for real-time forecasts of coastal hazards.

METHODOLOGY

In this study, we present an efficient and robust numerical model for the solution of the Nonlinear Shallow Water Equations. We investigate the behavior of the numerical approximations of these equations based on variations in spatial discretizations and time integrations. The proposed numerical structure is intentionally kept as lean as possible to provide the baseline for a computationally efficient solution structure. The model avoids the solution of Riemann problems commonly encountered in the discretization process of Finite Volume schemes to capture flow discontinuities (wave breaking).

The robustness and accuracy of the numerical model are verified and validated with a suite of benchmarking problems based on analytical solutions as well as on field experiments.

We further analyze the effect of the order of time integration and spatial differentiation on accuracy and stability of the solution.

Finally, we compare both CPU and GPGPU approaches for the numerical solution of the discretized equations and highlight the potential of GPGPUs versus conventional CPUs with a particular emphasis on NVIDIA's CUDA architecture.

RESULTS

We have developed an efficient and accurate numerical model to for the solution of depth-integrated Nonlinear Shallow Water Equations commonly encountered in the coastal engineering community and often used for tsunami computations. The model has proven to be well-balanced, convergent, and stable under a wide range of CFL-conditions. In general, high-order time discretization contributes to the stability and space discretization increases the accuracy but little improvement is found beyond second-order schemes. The code also manages to correctly compute a range of water flow problems including steady states, moving-boundaries, bottom friction as well as open and closed boundaries.

The presented scheme is specifically suitable for executions on GPGPUs where the efficiency increases with the size of the domain. This makes this model an attractive choice for computing large-scale problems and implementation into operational forecasting procedures.

CONCLUSIONS

The GPGPU code allows for the computation of long waves over large water bodies at fine resolution. The code presents a suitable base model, which can be easily extended with frequency dispersion or non-hydrostatic terms to build phase-resolving wave models.

The streamlined structure of the code makes the implementation of the scheme easier and the computation faster in comparison to existing CPU codes.

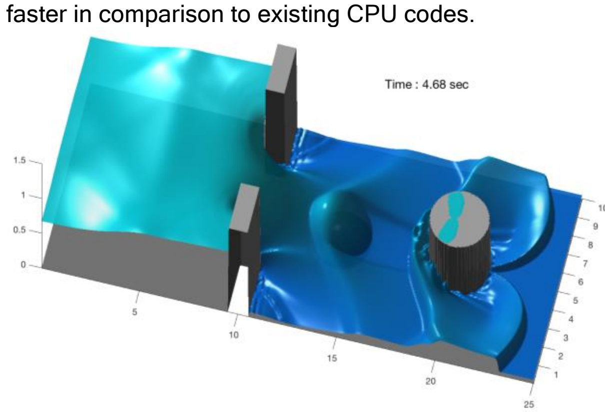

Figure 1 – Snapshot from a dambreak problem showing sharp shock fronts - computed by the GPGPU code.

REFERENCES

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