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The turn of the 21st century showed us vividly like never before the vast devastation and human loss that tsunamis can cause. The massive earthquakes and tsunami in Indonesia in 2004 and in Japan in 2011 brought to attention the need to develop better and faster forecasting and warning systems. Since the 1960s efforts have been made to study the behavior of tsunami waves to produce accurate simulations. From simple lineal models to ever increasing in complexity ones, we still have today the challenge to take the existing models to the next step.

The traditional approach for developing tsunami simulations has been to implement a CPU computation. However with the introduction of GPGPU computing in the middle of 2000's, new possibilities opened for researchers to explore the un-parallel speed-up provided by using GPU computation. By using CUDA, a C-language extension library, GPUs were available for general programing instead of limited to graphics; the inherit parallelism in graphics gave GPUs a natural advantage over CPUs with hundreds and thousands of cores dedicated exclusively to computing.

Taking advantage of this new technology we present a program that, while providing high accuracy and reliability, does not sacrifices speed or require excessive simplification to the modeling governing equations. In this study, the Shallow Water Equations (SWE) are solved to simulate completely on GPU the generation, propagation and inundation of tsunamis on the Indian Ocean.

SWE are a convenient set of governing equations to model tsunamis since they provide accuracy while keeping the complexity manageable. Since the domain of interest represents a large portion of the Earth the SWE in spherical coordinates are used (SSWE) to compute the tsunami propagation. This allows to take into account effects due to the curvature of the Earth and forces like Coriolis. However, to compute the inundation in areas of interest near the shore, the SWE in Cartesian coordinates are used instead since these areas represent a small region of just a few kilometers wide.

The method of characteristic is used to solve the SSWE, this provides an accurate way to find the solution while not being excessively computational demanding. A cubic interpolation is also implemented to the method, this permits us to obtain a third-order accuracy result and minimize the effects of dispersion and diffusion on long-wave propagation. Moreover a directional splitting is introduced in the equations to provide a more convenient way to handle the computation on GPU and keeping the computation stencil light.

Instead of following the tradition nested-grids method to compute the domain, we implement an AMR-style refinement. By using this approach we can produce a refinement that tracks complex coastal shapes, serves to save memory and computational resources, and provides a smooth transition through levels for the traveling wave as opposed to going through sudden resolution-jumps. Furthermore, specific customizations to the original block-based refinement were implemented to fit the purposes of this study. To focus computational resources on specific areas of interest, two refinement factors were introduced. Firstly, refinement by distance. The idea behind this refinement is that blocks close to the shoreline, where high degree of detail is required, have high resolution; while blocks in the open ocean have coarser resolutions. The second factor is the refinement by focal area. A focal area can be any polygonal area imposed on the domain, the effect of this area is to delimit the refinement to only blocks within. Any blocks outside the focal areas are refined up to a desired level, while blocks inside focal areas continue refining until higher resolutions. By using these two factors the domain's mesh generated, provides a great balance between resource-efficiency and accuracy where needed.

All the computation is performed on GPU. Three different kernels are developed to handle specific tasks: Inundation, Wet and Wall. While Inundation is self-explanatory, the difference between Wet and Wall lies in the boundary treatment. Both Wet and Wall kernels compute the SSWE for propagation, however the Wet kernel computes blocks that contain no dry points (land). The Wall kernel on the other side computes blocks that contain dry points and thus, boundary conditions such as coastal wave reflection. Only blocks marked specifically for inundation compute the tsunami run-up while the others implement a wall boundary condition. Moreover, Multi-GPU is developed to speed-up even further the computation. The domain decomposition is based on the Hilbert space filling curve and great care is taken to assure that all GPUs share the same load of work.

Validation tests were performed to guarantee the correct implementation of the SSWE. Also hindcast of the Indonesia 2004 tsunami is presented; gauges comparison and inundation maps in Sri Lanka and Phuket support the validity of our model and simulation. Moreover, exhaustive testing was done to guarantee a stable functioning of the program, named *TRITON*, under different initial conditions and user specification. The great results obtained by *TRITON* on speed, accuracy and flexibility allowed it to be implemented successfully as an operational tool for forecasting and warning advisory. Finally, in a collaboration project with The Regional Integrated Multi-Hazard Early Warning System for Africa and Asia (RIMES) based in Thailand, *TRITON* is deployed as their tsunami operational forecasting tool.