Implementation and integration of GPU-accelerated *easyWave* for instant tsunami propagation calculations in the *TRIDEC* tsunami early warning system demonstrator

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Usually, tsunami early warning systems store a large number of precomputed tsunami simulations in a database. Given earthquake event parameters either the best matches are picked from these precomputed simulations with the closest source model or a composite simulation is built by combining individual precomputed simulations. The construction, operation and maintenance of matching simulation databases, which normally weight several terabytes, not only require time consuming pre-computation and set-up but are also an IT and management challenge. Moreover, this approach may introduce problems if the closest precomputed source model and fault parameters do not necessarily coincide with the actual seismic observations.

An alternative way to quickly access simulated tsunami wave propagations in early warning systems based on the actual earthquake parameters is the on-demand computation with feasible algorithms, high performance hardware, and optimized code. Thus one simulation, or several simulations with varying granularity, covering several hours of tsunami wave propagation, and tailored to the actual situation can be computed within seconds. Since the main uncertainty in early warning is originated from the source parameters, furthermore, the on-demand computation allows fast re-computation in case of updated parameters.

The implementation and integration of GPU accelerated tsunami simulation computations have been an integral part of the project Collaborative, Complex, and Critical Decision-Support in Evolving Crises (TRIDEC, co-funded by EC FP7) to foster early warning with on-demand tsunami predictions based on actual source parameters. The work addressed (a) the re-engineering of the easyWave algorithm and code, (b) its porting from sequential CPU computation to parallel multi GPU processing, and finally (c) the integration and use in the TRIDEC tsunami early warning system (TEWS) demonstrator. Due to the gained time saving by the more than twenty-fold accelerated computation the launching of future application opportunities, such as the computation of coastal inundations and detailed run-ups, is addressed in successive activities.

Summarized, the initial CPU version of easyWave employs a light-weighted numerical scheme to simulate tsunami wave propagation and run-ups reasonable for early warning purposes. It computes spherical shallow water equations in linear approximation without coastal inundations and without detailed run-ups. Green's law is applied to estimate peak coastal tsunami amplitudes based on tsunami waves calculated for the validity limit of the linear shallow water model, usually for 20-50m depth. The existing code was re-engineered to serve the essential foundation for the GPU version. The parallelisation then was performed in the first step as native CUDA implementation for NVIDIA cards. Various optimization techniques were applied and their impact on performance was analysed for different hardware generations. Finally, the most optimised easyWave GPU version is wrapped by an abstraction layer for a service-like integration in the TRIDEC TEWS demonstrator. Thus operators on duty working with the TRIDEC Command and Control User Interface (CCUI) are enabled to request simulation computations based on earthquake event parameters, e.g. for the Portuguese system set-up two simulations computed in parallel, one for the Gulf of Cadiz region with 3 hours wave propagation and another one for the North East Atlantic region with 10 hours wave propagation. Amongst others the returned simulations provide the Estimated Time of Arrival (ETA) and the Estimated Wave Height (EWH) for Tsunami Forecast Points (TFP) and thus serve the input for the tsunami warning message generation and dissemination.

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