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On the accurate simulation of tsunami wave propagation

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A very important part of any tsunami early warning system is the numerical simulation of the wave propagation in the open sea and close to geometrically complex coastlines respecting bathymetric variations. Here we are interested in improving the numerical tools available to accurately simulate tsunami wave propagation on a Mediterranean basin scale. To this end, we need to accomplish some targets, such as: high-order numerical simulation in space and time, preserve steady state conditions to avoid spurious oscillations and describe complex geometries due to bathymetry and coastlines. We use the Arbitrary accuracy DERivatives Riemann problem method together with Finite Volume method (ADER-FV) over non-structured triangular meshes. The novelty of this method is the improvement of the ADER-FV scheme, introducing the well-balanced property when geometrical sources are considered for unstructured meshes and arbitrary high-order accuracy.

In a previous work from Castro and Toro [1], the authors mention that ADER-FV schemes approach asymptotically the well-balanced condition, which was true for the test case mentioned in [1]. However, new evidence[2] shows that for real scale problems as the Mediterranean basin, and considering realistic bathymetry as ETOPO-2[3], this asymptotic behavior is not enough. Under these realistic conditions the standard ADER-FV scheme fails to accurately describe the propagation of gravity waves without being contaminated with spurious oscillations, also known as numerical waves.

The main problem here is that at discrete level, i.e. from a numerical point of view, the numerical scheme does not correctly balance the influence of the fluxes and the sources. Numerical schemes that retain this balance are said to satisfy the well-balanced property or the exact C-property. This unbalance reduces, as we refine the spatial discretization or increase the order of the numerical method. However, the computational cost increases considerably this way.

Here we show technical details on how to implement a well-balance ADER-FV scheme for the non-linear shallow water equation. Finally, we present numerical simulations of realistic scenarios where unstructured meshes and high-order accuracy are mandatory.

[1] C.E. Castro and E.F. Toro. Solvers for the high-order Riemann problem for hyperbolic balance laws. J.Comput. Phys. 227(4):2481-2513, 2008.
[2] C.E. Castro and M. Käser. Tsunami Simulation with the ADER-DG Numerical Method. 7-12 September 2008, ESC 2008, 31st General Assembly, Creta, Greece.
[3] U.S. Department of Commerce. National oceanic and atmospheric administration, national geophysical data center. 2-minute gridded global relief data (etopo2v2), 2006.