FINAL REPORT PROGRAM LEFE

Program LEFE/MANU	Project Title UHAINA, un modèle communautaire pour la simulation des vagues extrêmes	Years 2017-2018
PI: Fabien Marche (Fabien.Marche@umontpellier.fr) IMAG, Univ. Montpellier Participating Laboratories : IMAG (Montpellier) , IMB & EPOC (Bordeaux), Inria, ICJ (Lyon)		

Context

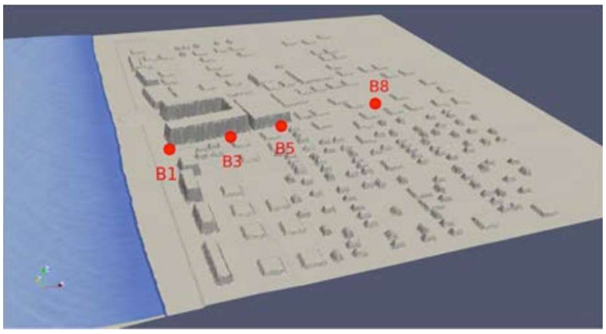
Nowadays, coastal areas host around 10% of the world's population and a huge amount of economic activities. Climate changes are expected to increase coastal flooding hazard in years to come. Assessing and predicting the risk has become a paramount importance factor and very high resolution simulations are mandatory. Hence the need to develop a high-performance model (UHAINA) to study nearshore propagation of energetic waves.

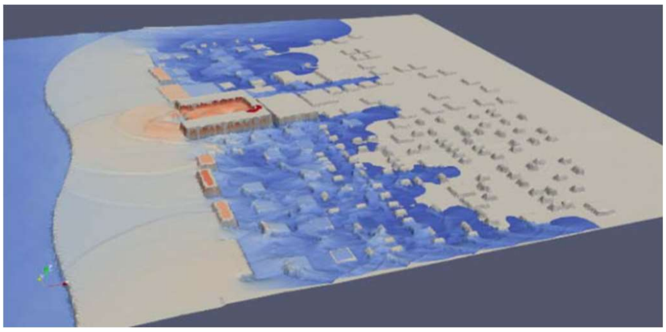
Objectives / scientific questions

1) implementation and benchmarking of the **hyperbolic part** (Saint-Venant (SV)) of the UHAINA model
2) implementation of the **dispersive part** of the model (Green-Naghdi (GN) equations)
3) develop some **new generating boundary conditions** for nonlinear dispersive models
4) develop efficient and accurate strategy to introduce **wave-breaking in GN equations**
5) develop **better high-order discontinuous Galerkin methods** especially designed for GN equations

Main results

1) **hyperbolic part of the Uhaina model***:* this part is implemented and validated (during the post-doc of S. Delmas and S. DeBrie), including robust wetting/ drying and an efficient strategy to account for shock waves based on an entropic viscosity method. Part of this work has been shown at JNGCGC 2018, see [P3]. In particular, a benchmark dedicated to urban flooding has been validated (Seaside experiment, see illustrations on next page),
2) **dispersive part of Uhaina model** (Green-Naghdi equations): a first working model has been obtained for the approximation of GN equations on unstructured meshes with discontinuous Galerkin (DG) methods in [P2]. For Uhaina and the HPC implementation, this part is now implemented but still under validation (post-doc of A. Filippini and S.M. Joshi).
3) A new method for the implementation of **generating boundary conditions for Boussinesq** (weakly dispersive and weakly nonlinear) models has been introduced in [P4]. This method relies on the definition of a dispersive boundary layer and allows to generate incoming waves without using generation/relaxation layers (which are usually 2 or 3 wavelengths) that may artificially enlarge the computational domain. The extension of this method to fully nonlinear models (GN) is still under investigation.
4) Wave breaking **in GN equations** is a difficult topic. During the project, we investigated two different strategies. The first one relies on a dynamic switching between SV and GN, following the works initiated during the Ph.d. of M. Tissier in 2012. The second one relies on the introduction of an additional variable (namely the enstrophy), additional terms which account for the energy dissipation during breaking, and additonal equations which accounts for the time evolution of the enstrophy in the model. This has lead to a first publication in [P5].
5) after [P2], we have introduced **a new discontinuous-galerkin (DG) formulation** especially designed for GN equations in [P1]. A new symmetric weighted internal penalty (SWIP-DG) method is designed, which allows, in comparison with [P2], to consider a symmetric formulation for the elliptic problems, hence improving the runtime efficiency. Such an Internal Penalty DG formulation is implemented into Uhaina instead of the (unsymmetric) LDG approach of [P2].





Three dimensional views of the Seaside numerical simulation performed with UHAINA (taken from [P3]), at two different times of the computation: before (left) and just after (right) the tsunami arrival. Red bullets correspond to some gauges positions.

***Future of the project** :*

The future research topics will be dedicated to

1) *the validation and benchmarking of Uhaina on large scale problems including all the targeted features,*
2) *the implementation of operational features (pre and post processing, boundary conditions),*
3) *the optimization of the algorithms and the parallel implementation,*
4) *the investigation of more efficient discrete formulations relying on hybridization (HDG and/or HHO)*
5) *the investigation of a heterogeneous GP-GPU implementation,*

Nombre de publications, de communications et de thèses

During this project, we have produced:

1) *5 publications in international peer-reviewed journals*
2) *1 peer-reviewed conference proceedings*
3) *2 post-doctoral positions related to Uhaina has been provided*
4) *1 Ph.D. thesis has started in 2018 (M. Zefzouf, IMAG)*

[P1] D. Di Pietro, F. Marche. Weighted Interior Penalty discretization of fully nonlinear and weakly dispersive free surface shallow water flows, *J. Comput. Phys*., 355, 285-309, 2018.

[P2] A. Duran, F. Marche. A discontinuous Galerkin method for a new class of Green-Naghdi equations on unstructured simplicial meshes, *Applied Math. Model*., 45, 840-864, 2017.

[P3] A. Filippini, S. De Brye, V. Perrier, F. Marche, M. Ricchiuto, D. Lannes, P. Bonneton. UHAINA : A parallel high performance unstructured adaptive nearshore wave model. In *Proceedings of the 15th Journées Nationales G énie Côtier et Génie Civil*, Paralia edition, 2018.

[P4] D.Lannes, L. Weynans. Generating boundary conditions for a Boussinesq system. under review, 2019.

[P5] G.L. Richard, A. Duran. A new model of shoaling and breaking waves. Part 2. Run-up and two-dimensional waves. *J. Fluid. Mech*, 867, 2019.