# Offer #2024-07351

# PhD Position F/M Advancing Flood Modeling: Integrating High-Order Numerical Methods with Sub-Cell Limiting Techniques for Accurate Urban Flooding Prediction

**Contract type :** Fixed-term contract

**Level of qualifications required :** Graduate degree or equivalent

**Fonction :** PhD Position

## About the research centre or Inria department

The Inria center at the University of Bordeaux is one of the nine Inria centers in France and has about twenty research teams.. The Inria centre is a major and recognized player in the field of digital sciences. It is at the heart of a rich R&D and innovation ecosystem: highly innovative SMEs, large industrial groups, competitiveness clusters, research and higher education players, laboratories of excellence, technological research institute...

## Context

- Project **RESCUER HORIZON-MSCA-2022-DN 101119437**
  Resilient solutions for Coastal, Urban, Estuarine and Riverine environments
- The position also involves travels to other partners (secondments) as declared in the Grand Agreement

This project takes place within ongoing collaborations between the Inria CARDAMOM team and UNIVPM ( Universita Politecnica delle Marche), AAU (Aalborg Universitet) and BRGM.

## Assignment

**Assignments :**

Strategic planning to mitigate the effects of floods, induced within an urban environment by either heavy rainfall or other sources related to river and sea actions, is crucially important due to its paramount importance for people (e.g., pedestrian), objects, and structures. The only non-destructive way to assess these dangers is by advanced flow modeling techniques, which allow accurate forecasts of the hydrodynamics in urban areas.

The objective of this PhD is to develop a modeling framework for urban flooding simulations that integrates precise representations of topography and built structures using the Discontinuous Galerkin (DG) numerical method. Ensuring high-resolution descriptions of both coastlines and structures, with accuracies of maybe less than a meter, is crucial for accurately depicting flooding dynamics. The primary challenge lies in managing complex and irregular bathymetric data represented by polynomials on unstructured grids. This framework must effectively handle interactions between irregular bathymetric data and flooding fronts (wet/dry transitions), potentially incorporating non-submerged floating structures. A well-balanced scheme is imperative to avoid spurious and non-physical waves arising from numerical discretization-induced bathymetric variations.

The idea is to explore sub-cell models and sub-cell resolution strategies combined with some nonlinear numerical method. For example one avenue of exploration lies in the usage of sub-cell approximations that may allow to construct well balanced schemes preserving the high resolution see for eg [1]. Further more the integration of sub cell techniques can be instrumental in maintaining water positivity around wet/dry areas [2].

It is known that high order DG methods may produce spurious oscillations in the presence of discontinuities or steeply varying gradients, i.e. Gibbs phenomenon a possible way to treat this is the sub cell nonlinear approximations for the topography to avoid these spurious oscillations.

Furthermore, the integration of individual cell models could be extended to deal with friction phenomena and adapting to the presence of floating structures, allowing an integrated simulation framework that captures a variety of real-world scenarios [3,4].

The implementation will be carried out within the UHAINA codebase [5], a phase-resolving free surface wave model. UHAINA is built on the Aerosol platform, offering extensive capabilities such as arbitrary high-order finite element discretizations, hybrid meshes, and an advanced programming environment optimized for performance and high-performance computing (HPC).

Anticipated outcomes include improvement on academic tests, and applications in operational context to realistic events benefiting from BRGM'experience in the matter, and experiments from other partners benefiting from consortium data

The resulting numerical scheme will be applied to a case study of urban flooding, with comparisons made against experimental data provided by UNIVPM.

[1] A. Meister and S. Ortleb. A positivity preserving and well-balanced DG scheme using finite volume subcells in almost dry regions. Appl. Math. Comp., 272:259–273, 2016.

[2] Haidar, Ali and Marche, Fabien and Vilar, Francois. A posteriori finite-volume local subcell correction of high-order discontinuous Galerkin schemes for the nonlinear shallow-water equations. Journal of Computational Physics,452:110902,2022.

[3] Edwige Godlewski, Martin Parisot, Jacques Sainte-Marie, Fabien Wahl. Congested shallow water model: on floating body.*SMAI Journal of Computational Mathematics*, 2021, 6, pp.227-251.

[4] U. Bosi, C. Eskilsson, A.P. Engsig-Karup, and M. Ricchiuto,A spectral/hp depth-integrated model for nonlinear wave body interaction,*Comp. Meth. Appl. Mech. Eng.* 348, pp. 222-249,2019

[5] Filippini, A. G., De Brye, S., Perrier, V., Marche, F., Ricchiuto, M., Lannes, D., & Bonneton, P. (2018, May). UHAINA: A parallel high performance unstructured near-shore wave model. In *Journées Nationales Génie Côtier-Génie Civil* (Vol. 15, pp. 47-56). Editions Paralia.

**Collaboration :**

The recruited PhD student will collaborate with colleagues in CARDAMOM team and with collaborators in UNIVPM ( Universita Politecnica delle Marche), AAU (Aalborg Universitet) and BRGM.

## Main activities

- Development of sub-cell models within the DG framework , preserving the WB, control positivity and keeping the high resolution.
- Examining sub- cell polynomial approximations for the topography.
- Developing sub-cell models for friction and floating structures.
- Participation on dedicated laboratory tests that will be executed at UNIVPM to study the local hydrodynamics generated in correspondence of irregularities, such as building openings, courtyards, block porosity, obstacles.
- Verification and validation of the produced code with standard benchmarks and the above experimental data.

Additional activities:

- Participate in the training activities as described in the Grand Agreement.

## Skills

Technical skills and level required : The candidate must have a master degree in applied mathematics and scientific computing. Knowledge in programming (C, C++, Fortran or Python) will be highly appreciated.

Languages : English at good working level.

Relational skills : The candidate must be able to work in an international environment involving multiple collaborators, and be willing to travel.

## Benefits package

- Subsidized meals
- Partial reimbursement of public transport costs
- Leave: 7 weeks of annual leave + 10 extra days off due to RTT (statutory reduction in working hours) +

possibility of exceptional leave (sick children, moving home, etc.)
- Possibility of partial teleworking and flexible organization of working hours
- Professional equipment available (videoconferencing, loan of computer equipment, etc.)
- Social security coverage

## Remuneration

remuneration calculated according to the "MSCA Doctoral Networks 2022" scale

## General Information

- **Theme/Domain :** Numerical schemes and simulations
- **Town/city :** Talence
- **Inria Center :** Centre Inria de l'université de Bordeaux
- **Starting date :** 2024-09-01
- **Duration of contract :** 3 years
- **Deadline to apply :** 2024-05-17

## Contacts

- **Inria Team :** CARDAMOM
- **PhD Supervisor :**
  Kazolea Maria / maria.kazolea@inria.fr

## About Inria

Inria is the French national research institute dedicated to digital science and technology. It employs 2,600 people. Its 200 agile project teams, generally run jointly with academic partners, include more than 3,500 scientists and engineers working to meet the challenges of digital technology, often at the interface with other disciplines. The Institute also employs numerous talents in over forty different professions. 900 research support staff contribute to the preparation and development of scientific and entrepreneurial projects that have a worldwide impact.

**Warning** : you must enter your e-mail address in order to save your application to Inria. Applications must be submitted online on the Inria website. Processing of applications sent from other channels is not guaranteed.

## Instruction to apply

- Applicants must be doctoral candidates, i.e. not already in possession of a doctoral degree at the date of recruitment.
- Mobility rule: researchers must not have carried out their main activity (e.g. work, studies) in the host country for more than 12 months in the 3 years immediately before their recruitment date.

The list of documents required to apply is as follows:

 a CV containing web links to publications and master's thesis (if applicable),

 a covering letter describing, in particular, interest in the subject as well as a description of the master's work (or equivalent) ;

 a transcript of marks for the last 2 years;

 at least one letter of recommendation from the supervisor of the master's course (or equivalent) sent directly by the author to the future thesis supervisor.

**Defence Security :**
This position is likely to be situated in a restricted area (ZRR), as defined in Decree No. 2011-1425 relating to the protection of national scientific and technical potential (PPST).Authorisation to enter an area is granted by the director of the unit, following a favourable Ministerial decision, as defined in the decree of 3 July 2012 relating to the PPST. An unfavourable Ministerial decision in respect of a position situated in a ZRR would result in the cancellation of the appointment.

**Recruitment Policy :**
As part of its diversity policy, all Inria positions are accessible to people with disabilities.