Numerical analysis of models for free surface flows

Level of qualifications required: Graduate degree or equivalent
Fonction: PhD Position
Level of experience: Recently graduated

Context

The research program of ANGE consists in deriving and analyzing models (PDE) of reduced complexity with respect to the Navier-Stokes equations and enriched with respect to the classic Shallow Water system. This process provides a hierarchy of models mainly of hyperbolic type (conservation laws).

The modeling, the analysis and the simulation of geophysical flows are complex and challenging topics upon applied research and engineering. The growing importance of sustainable development issues coupled with the complexity of the aforementioned problems imply to go further than the classical shallow water type systems. The issues investigated within the team mainly concern gravity driven flows such as hazardous flows (flooding, rogue waves, landslides, ...), sustainable energies (hydrodynamics-biology coupling, biofuel production, marine energies, ...), risk management and land-use planning (morphodynamic evolutions, early warning systems, ...).

Assignment

Depending on the skills of the candidate, the post-doctoral position will focus on one of the following questions.

1. Numerical treatment of source in conservation laws

Free-surface flows are classically modelled by means of reduced-complexity systems including the shallow water (SW) model. The numerical simulation of the SW model has been extensively addressed in the literature in the framework of conservation laws. Consequently, there exists a wide range of numerical schemes dedicated to such problems.

When taking into account source terms, additional issues occur due to the fact that equilibrium states become nontrivial. In some applications, it is crucial to consider numerical strategies that preserve such equilibria. For instance, the bottom topography induces equilibria like the "lake-at-rest" state. The hydrostatic reconstruction is then a tool to ensure the preservation of that state by a numerical scheme.

The source term that is considered in this research project is related to the rotation of Planet Earth as part of the ANGE project. Do Minh Hieu's PhD thesis (2014-2017) was devoted to the analysis of issues related to the resulting equilibrium states, in particular in the low Froude regime. It lead to the derivation of corrections to apply to Goudonov-type schemes in order to provide accurate results. Strategies were assessed by studying the linear wave equation: depending on the dimension (1 or 2) and the discretisation grid (collocated or staggered), a catalogue of modified schemes was proposed and compared in the linear case (stability conditions, discrete kernels, orthogonality-preserving property, ...). It was finally extended to the nonlinear SW equations by means of numerical simulations on a collocated grid.

2. Model reduction

Hyperbolic systems, which record avalanche faults, are known to give rise to very complex simulations that can hardly be accelerated numerically: the low regularity of solutions gives rise to a space of solutions that is difficult to reduce. In addition, the finite propagation speed generates deeply sequential computations and makes the parallelization in time particularly complex. To tackle these scientific locks, the general strategy that we adopt consists in taking advantage of the information known a priori about the solutions. This strategy allows to restrict their parameters to small dimensions or to carry out a preliminary analysis of the dynamics at stake. The following program aims to design and study methods of reduction and parallelization in time, focusing on the specific example of Saint-Venant type equations, for which the ANGE team is a specialist. The team's know-how will enable us to take advantage of qualitative properties of the solutions.

Three independent parts make up the project: the first part deals with the development of model-reduction techniques and the second part focuses on the problem of parallelization in time simulation. Finally, a last part is devoted to the study of implicit schematics for Saint-Venant.

Investigations must be carried out to analyse the nonlinear case and to continue to propose robust and accurate strategies that can be actually implemented in industrial codes. Extensions to staggered
grids must be performed. Complementary approaches like Despres & Buet’s paper (Applied Math. Comput., 2016) will also be considered.

2. Numerical optimization and high performance computing

This PhD thesis subject is part of a collaboration with IPGP (A. Mangeney) and Paris-Est Univ. (F. Bouchut).

Main activities

- Research in applied mathematics
- Numerical analysis of PDEs
- Numerical scheme and scientific computing
- Comparison of simulation with experimental data

Skills

The candidate should have a solid background in applied mathematics, analysis/numerical analysis of PDEs e.g. hyperbolic PDEs.

Benefits package

- Subsidised catering service
- Partially-reimbursed public transport

Remuneration

Gross Salary per month: 1 982 € the first 2 years and 2 085 € the last year