Fast modeling in geosciences

Master 2 internship in Applied Mathematics

Context

Environmental numerical modeling is a crucial issue of numerical forecasting systems (meteorology, oceanography, atmospheric chemistry, rivers and floods, climate, etc.). Environmental numerical models are based on mathematical equations representing the physics of the system under study.

Need for fast systems

It is often crucial to have computationally efficient numerical models, in particular in the two following contexts :
– “many-query” context ;
– “real-time” context.

Many-query means that we need to perform a lot (100, 1000 or more) runs of the model. Let us give some examples of many-query procedures. The first example is the one of **global sensitivity analysis**, which is an important step for environmental studies. Indeed, uncertainties are numerous, and it is therefore important to measure the impact of a parameter on the quality of the solution and identify "sensitive" parameters in the sense that a small change in this parameter gives a wide variation in the solution of the model. Sensitivity analysis is a set of stochastic or deterministic methods, which measure the sensitivity of a parameter in the model. Stochastic global sensitivity analysis requires the implementation of Monte-Carlo methods (e.g., if one want to compute Sobol’s indices), which in turn require many runs in order to give an accurate estimation.
Another example would be **optimisation of model parameters**. Indeed, after sensitibity analysis has been performed, the sensitive parameters need to be precisely defined in the model. As they are usually unknown (uncertain), we may want to implement an optimisation method (inverse methods or data assimilation, e.g.) in order to approximate them at best. Optimisation methods often imply the implementation of iterative descent methods, which also require many model runs. Either way, in this framework, fast systems are mandatory.

Real-time context is self-explanatory : the model output needs to be immediately accessible to the user, and therefore fast models are required.

Model reduction

It consists in a set of methods that allow to reduce the computational dimension of the model, and therefore allow for acceleration and computational gains. When working with a non-reduced model, we first discretize the (spatio-temporal) domain, then we solve equations on the chosen grid, that is to say we seek the values of the unknown variables at each point of the grid (sometimes thousands of points). Classical methods include finite differences, finite elements, finite volume, and so on. Dimension reduction aims at reducing the number of variables to be computed by projecting the equations on a well chosen but smaller basis, well-suited for the problem. In other words, the unknown of the problem are now the coefficients in the new (smaller, reduced) basis, so that the computational dimension is reduced and the model is computationally more efficient.

Objectives

The main objective of this internship is to understand, implement and compare various numerical models and reduced models for the ocean. The Shallow-Water equations will be implemented using explicit and/or implicit methods, both will be reduced (using different choices of reduced bases), and the computational efficiencies of various methods will be compared in order to identify the fastest.

Work outline

This internship will be balanced between the following three aspects :
– bibliography on different reduction methods ;
– adaptation for a specific Shallow-Water partial differential equations model ;
– implementation using C/C++/Matlab.

Required skills

Numerical methods for Partial Differential Equations ; C/C++/Matlab.

Date and place of the internship

The internship will take place in the Laboratory Jean Kuntzmann, in the AIRSEA Inria team (Clémentine Prieur and Maëlle Nodet).

Continued PhD

This internship could lead to a thesis in the AIRSEA team.

Gratification

Traditional for an internship (560 euros / month).

Contacts

Maëlle Nodet, Clémentine Prieur (UGA/CNRS/INRIA)
`maelle.nodet@inria.fr`, `clementine.prieur@imag.fr`