CS/AM Internship: MPI parallelization of the SWEET PDE solver code

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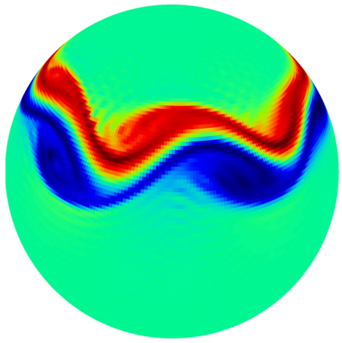
SWEET (`https://sweet.gitlabpages.inria.fr/sweet-www/`) is a PDE solver software that allows a fast exploration, investigation, and prototyping of time discretization methods for PDE solvers that use global spectral methods (Fourier for Cartesian systems & spherical harmonics on the sphere).

SWEET targets, in particular, to

- accelerate research around the development of (numerical) time integration methods
- investigate new ways to express parallelization
- do some early investigations of scalability of novel time integration methods (e.g., parallel-in-time).



Snapshot of a barotropic instability benchmark on the sphere computed with SWEET.

Rather than using operational software codes, in which it is hard to research different forms of time integration, SWEET allows to do rapid development due to a clear and powerful software design. Since it is developed with a co-design of applied mathematics and high-performance computing, HPC performance benchmarks, hence real speedup measurements, can show the potential impact once applied to operational codes.

Since its beginning, it has been successfully used to steadily pioneer the research on parallel-in-time methods targeting climate/weather simulations by investigating time integration for the horizontal parts as part of shallow-water equations, see publications at `https://sweet.gitlabpages.inria.fr/sweet-www/publications/`.

Although there are currently even more time integration approaches actively researched within SWEET, there is one drawback, as explained in the following section.

1 Goal

Regarding solvers related to the time dimension, it supports OpenMP and MPI. Hence, it is ready for large-scale systems for this. However, one main limiting factor is the spatial resolution, where only OpenMP is supported so far. A support of distributed memory parallelization is highly desirable to investigate PDEs with an even higher resolution. The main goal of this project will be to work towards parallelizing the space discretization with MPI.

2 Objectives

1. Objective "**1D discretization**":
   Your first objective would be to develop a 1D Fourier-based discretization. This will be based on

the existing 2D implementation, hence, a simplification of it. This will make you familiar with how SWEET works.

This will also include the implementation of 1D-based simulations such as the Burgers' equation within SWEET.

2. Objective "**1D MPI parallelization for Cartesian systems**":
The first step with MPI will be to parallelize the 1D discretization with MPI which includes parallelizing the Fourier transformations.

3. Objective "**2D MPI parallelization for Cartesian systems**":
The next step will be to parallelize the 2D discretization with MPI.

4. Objective "**2D MPI parallelization for the Sphere**":
Depending on the success of the previous objectives, the last step consists of an MPI parallelization of the spherical-harmonics-based discretization.

3 Prerequisites

In order to ensure a successful internship for you and us, please ensure that you fulfill all or at least most of the following prerequisites. Please point out your qualifications in the application letter (see below).

- Basic understanding of partial differential equations (Fourier-based analysis)
- Being familiar with High-Performance Computing (e.g., OpenMP / MPI / ...).
- Willingness to work independently (maybe previous experience in an internship/lab/etc.).

4 Application

To apply to this internship, send an Email to martin.schreiber@univ-grenoble-alpes.fr, including your CV, a transcript including all your grades (Bachelor + Master), and a brief explanation of why you are interested in this project.