Plan Overview

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Title: Parallel-in-time resolution of the shallow water equations on the rotating sphere using spherical harmonics and semi-Lagrangian discretization

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Template: USP Template - Minimum

Project abstract:

This postdoctoral project aims to study the numerical resolution of atmospheric fluid dynamics models using parallel-in-time schemes. As a component of complex climate and weather prediction models, atmospheric modelling must provide accurate numerical solutions, which are computationally expensive; therefore, temporal parallelization is a promising approach for reducing the high computational times necessary for performing these accurate simulations. We focus on the resolution of the shallow water equations on the rotating sphere, a two-dimensional model widely used in the atmospheric modelling community since it is a simplified model presenting most of the properties and challenges of more complex ones. The equations are discretized in space and time using respectively spherical harmonics and a semi-Lagrangian method, two approaches widely used in this domain. The temporal parallelization will be performed using different methods, e.g. the parareal, the MGRIT and the PFASST, which have been recently applied to the resolution of the SWE on the rotating sphere, but combined with other temporal discretizations. For this application, the temporal parallelization is especially challenging because parallel-in-time methods presents instabilities and/or slow convergence when applied to hyperbolic or advection-dominated problems, such as the ones arising in atmospheric modelling. Recently, the combination of the parareal method with a semi-Lagrangian discretization showed promising results for improving its stability. Therefore, we consider this approach as guideline in this work and we investigate further improvements of the parallel-in-time methods. The proposed numerical schemes will be executed, validated and compared in real parallel high performance computing systems.

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Copyright information:

Parallel-in-time resolution of the shallow water equations on the rotating sphere using spherical harmonics and semi-Lagrangian discretization - Description of Data and Metadata produced by the project

This postdoctoral project will lead to the formulation of parallel-in-time numerical methods, which will be computationally implemented for validation, testing and studying. Numerical simulations using benchmark tests for the shallow water equations on the rotating sphere will be performed, and the output numerical solutions and the wall-clock time of the simulations will be collected for evaluating the accuracy and performance of the methods. Detailed studies may consider various types of tests (for studying e.g. the influence of nonlinear interactions) and different execution configurations (e.g. using different numbers of parallel processors).

The implementation of the proposed methods will be made in C++ language. Additional tools and scripts for analysis and presentation of the numerical results (e.g. graphs, plots of the numerical solution) may be implemented in Python. In a first moment, during the initial development, improvement and study stages, the proposed numerical methods will be implemented as stand-alone programs. After consolidated, they may be incorporated to the SWEET platform, which is also developed in C++, for further developments and improvements. The codes will be developed having in sight a parallel execution in High Performance Computing systems.

All the developed numerical codes, as well as the main numerical results, including the ones to be used for scientific communication (papers and conferences), will be maintained and stored in a collaborative Git repository hosted in GitHub. This platform allows to store, track and recover development and data history. The candidate João Guilherme Caldas Steinstraesser will be the main responsible for the management of this GitHub repository.

The SWEET platform is also maintained in GitHub (https://github.com/schreiberx/sweet). Therefore, the storage and backup policy described above will also apply to developments performed in SWEET.