Non-hydrostatic atmospheric modelling

M2 internship 2024

Overview

The numerical models used for climate studies include a solver for the atmospheric flow. The DYNAMICO solver is a massively parallel finite volume/finite difference solver on a spherical Voronoi mesh, running on CPUs and GPUs [1,2]. It uses the hydrostatic approximation, which avoids certain numerical difficulties without loss of accuracy for large-scale atmospheric circulation.

Studying small-scale atmospheric flows requires so-called non-hydrostatic solvers, which solve the compressible Euler equations with gravity. This system is stiff and requires implicit time integration, at least partially, without compromising the massively parallel performance of the solver. An original implicit-explicit time integration (IMEX) [3,4] has been developed for the DYNAMICO solver, but it exhibits numerical instabilities in some cases.

The aim of the internship is to systematically examine the stability of this scheme using an implementation in Julia [5,6], a high-level language which facilitates the exploration of simplified variants and configurations while also allowing heavy configurations and/or GPU computing.

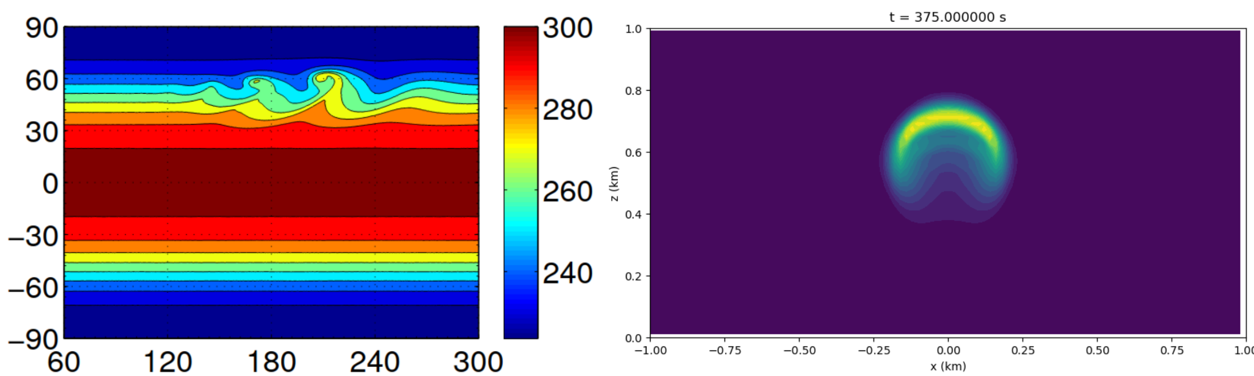

Figure 1: Left: Global map of temperature at around 1500 m altitude during the development of an idealized low-pressure system. Right: Air temperature during the vertical convection of an air mass.

Proposed work

The planned programme has several steps with some overlap:

1. Appropriation of tools and methods :
   - self-training in the Julia language (numerous tutorials available online)
   - simple numerical experiments with an existing Julia implementation of the DYNAMICO hydrostatic solver (Fig. 1, left)
   - Julia port of existing Python code implementing the IMEX scheme in a simplified 2D configuration (Fig. 1, right)
2. Characterisation of stability in simplified configurations: dependence of scheme stability on horizontal and vertical resolution, time step, ground slope, numerical parameters of the scheme.
3. Characterisation of numerical stability in three dimensions of space (3D):

- inclusion in the 3D solver of a horizontal spectral discretization in order to separate the problem of temporal stability from that of spatial discretization
- non-hydrostatic extension of the 3D solver (spectral and finite volumes)
- identification of stable / unstable configurations

Working environment

The work will take place at the Dynamic Meteorology Laboratory at École Polytechnique, under the supervision of Thomas Dubos (LMD), co-leader of the DYNAMICO code. The trainee will have access to the IPSL/ESPRI computing cluster, which includes CPU and GPU nodes. All the code involved in the work is distributed under an open source licence and versioned with git.

The ideal candidate

- has a background in numerical methods and scientific computing
- is familiar with Python and git, as well as a compiled language (C++/Fortran/Julia)
- is technically and intellectually independent and open to new scientific computing technologies
- is rigorous and systematic in his or her work, as well as its presentation and discussion
- is interested in the application of scientific computing to climate challenges

Contact

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Références

1. Dubos et al. (2015)
2. DYNAMICO
3. Weller et al. (2013)
4. IMEX scheme in Python
5. Julia language
6. DYNAMICO numerics in Julia