

Limited-area Geophysical Fluids Modeling Framework (L-GAME) **Handbook**

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All physical quantities in this document are to be multiplied with their respective SI units.

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Chapter 1

Overview

L-GAME is the application of the theory and numerics of GAME to a quadrilateral latitude-longitude grid in a regional domain.

Chapter 2

Code structure

The code of the model resides in the directory `src`.

2.1 Spatial operators

- Coriolis: [1] and [5] modified by [3]
- kinetic energy: [2]

2.2 Time stepping

A fully Eulerian time stepping is employed. The basic building structure is Runge-Kutta second order (RK2). In the vertical, at every substep, an implicit column solver is used, which makes it possible to violate the CFL criterion of vertically propagating sound and fast gravity waves. This has the cost of decreasing the accuracy of these modes, which is however a bearable trade-off, since these waves are of low meteorological relevance. Furthermore, a forward-backward scheme is used, where the divergence term is backward.

Chapter 3

Installation

3.1 Dependencies

The following dependencies must be installed before being able to successfully build the model:

- `geos95` (<https://github.com/OpenNWP/geos95>)
- `atmostracers` (<https://github.com/OpenNWP/atmostracers>)
- Clone our fork of the RTE+RRTMGP repository: `git clone https://github.com/OpenNWP/rte-rrtmgp`
- Python and pip (only needed for the plotting routines): `sudo apt-get install python3 python3-pip`
- Python packages (only needed for the plotting routines): `pip3 install matplotlib numpy netCDF4`

3.2 Building

CMake is used for building L-GAME. Execute `./compile.sh` to build the model.

Chapter 4

Grid generation

4.1 Vertical grid structure

So far, only a horizontal grid has been examined. The grid generator, however, shall produce full three-dimensional grids. In order to simplify matters, the following conventions are made:

- Since the vertically oriented primal vector points have the same horizontal coordinates as the primal scalar points, their horizontal numbering is also the same.
- Since the vertically oriented dual vector points have the same horizontal coordinates as the dual scalar points, their horizontal numbering is also the same.

4.2 Horizontal grid properties

4.3 Vertical grid properties

The vertical grid structure is determined by the following properties:

- the height of the top of the atmosphere, specified via the parameter TOA
- the number of layers, specified via the parameter NUMBER_OF_LAYERS N_L
- the number of layers following the orography, specified via the parameter NUMBER_OF_ORO_LAYERS N_O
- the stretching parameter β , which can be set in the run script
- the orography, specified via the parameter ORO_ID

The generation of the vertical position of the grid points works in three steps:

1. First of all, vertical positions of preliminary levels with index $0 \leq j \leq N_L$ are determined by

$$z_j = T\sigma_{z,j} + B_j z_s, \quad (4.1)$$

where T is the top of the atmosphere, $\sigma_{z,j}$ is defined by

$$\sigma_{z,j} := \left(1 - \frac{j}{N_L}\right)^\alpha, \quad (4.2)$$

where $\alpha \geq 1$ is the so-called *stretching parameter*, z_s is the surface height and B_j is defined by

$$B_j := \frac{j - (N_L - N_O)}{N_O}. \quad (4.3)$$

2. Then, the scalar points are positioned in the middle between the adjacent preliminary levels.
3. Then, the vertical vector points are regenerated by placing them in the middle between the two adjacent layers.
4. Finally, the vertical positions of the other points are diagnosed through interpolation.

4.4 How to generate a grid

Chapter 5

Running the model

5.1 Dynamics configuration

5.2 Physics configuration

5.2.1 Local thermodynamic equilibrium option

Assuming a local thermodynamic equilibrium in a heterogeneous fluid boils down to assuming that all constituents have the same temperature. This reduces the complexity of the simulation by about 40 %, since now internal energy densities are not prognostic variables anymore.

5.3 Coupling to the radiation field

GAME employs the so-called RTE+RRTMGP (Radiative Transfer for Energetics + Rapid and Accurate Radiative Transfer Model for Geophysical Circulation Model Applications-Parallel) [4], [6] scheme.

Chapter 6

Configuring output

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