Global ESMs are complex systems made of heterogeneous components, that require a substantial amount of effort to work correctly and use the resources wisely. The goal of running these models using grids on the order of 1 km will be impossible to achieve without using adequate optimization techniques.

Earth System Models (ESMs) consume billions of computing hours every year. Our motivation is to optimize these models to save both time and energy, and allow further increases in resolution and complexity to improve their capabilities of simulating small-scale features and reduce the impact of the parametrizations.

Methodology to evaluate Earth System Models

Complex models require complex studies. Several techniques are needed to optimize an ESM:

Mathematical and Computational study
Understand the algorithms used and the overhead or drawbacks introduced by the parallel implementation.

Scalability Study
The evaluation of an ESM requires deep knowledge about the complex workflows and experiments done [1].

Profiling Study
General and oriented profiling analysis for ESMs [2].

Introducing optimizations
Computational improvements, optimizing or introducing new approaches [3].

Reproducibility study
Keeping in mind the chaotic nature of climate models, evaluate the impact in accuracy and reproducibility of the model after applying the proposed optimizations [4].

Performance tools [5] are essential to study the behavior of ESMs:
- Extra: is a package used to instrument the code. It generates trace-files with hardware counters, MPI messages and other information.
- Paraver: is a browser used to analyze both visually and analytically trace-files.

Dimemas, Clustering, Folding... Other tools to evaluate ideal conditions, gather performance data...

The view of a trace consists of threads or processes on the Y axis and the timeline on the X axis. The base trace (figure on the right) shows MPI functions, where each type of call is identified by a color. Blue color represents a computation area.

Other traces can contain PAPI events to collect information regarding the microprocessor performance. Colors represent in this case a gradient between maximum and minimum values.

Climate predictions have complex workflows. New metrics are needed to evaluate the computational efficiency.

- The simulation does not only involve the execution of a model during a sequence of time steps (represented by the sim job).
- The experiment adds complexity in the horizontal for ensembles (members with perturbations in the initial conditions).
- The experiment adds complexity in the vertical, running long simulations divided into chunks and including pre- and post-processing.

Why do we need to evaluate Output and Coupling cost?
- The execution of a coupled model is complex. Different components run in parallel exchanging some information and adding some extra overhead (Communication and Interpolation Time). Load imbalances produce extra waiting time as well.
- The execution of each component could involve some irregular extra overhead, such as output processing or calculations occasionally done, such as radiation.

References
[1] Yepes-Arbo, X. et al., 2016: “Scalability and performance analysis of EC-Earth 3.2.0 using a new metric approach (Part II).” Barcelona Supercomputing Center