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Simulation-based performance analysis of EC-Earth 3.2.0 using Dimemas

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Earth System Models (ESMs) are complex applications executed in supercomputing facilities due to their high demand on computing resources. However, not all these models perform a good resources usage and the energy efficiency can be well below a minimum acceptable.

One example is EC-Earth, a global coupled climate model which integrates different component models to simulate the Earth system. The two main components used in this analysis are IFS as atmospheric model and NEMO as ocean model, both coupled via the OASIS3-MCT coupler.

Preliminary results proved that EC-Earth does not have a good computational performance. For example, the scalability of this model using the T255L91 grid with 512 MPI processes for IFS and the ORCA1L75 grid with 128 MPI processes for NEMO achieves 40.3 of speedup. This means that the 81.2% of the resources are wasted.

Therefore, it is necessary a performance analysis to find the bottlenecks of the model and thus, determine the most appropriate optimization techniques. Using traces of the model collected with profiling tools such as Extrae, Paraver and Dimemas, allow us to simulate the model behaviour on a configurable parallel platform and extrapolate the impact of hardware changes in the performance of EC-Earth.

In this document we propose a state-of-art procedure which makes possible to evaluate the different characteristics of climate models in a very efficient way. Accordingly, the performance of EC-Earth in different scenarios, namely assuming an ideal machine, model sensitivity and limiting model due to coupling has been shown.

By simulating these scenarios, we realized that each model has different characteristics. With the ideal machine, we have seen that there are some sources of inefficiency: about a 20.59% of the execution time is communication; and there are workload imbalances produced by data dependences both between IFS and NEMO and within each model.

In addition, in the model sensitivity simulations, we have described the types of messages and detected data dependencies. In IFS, we have observed that latency affects the coupling between models due to a large amount of small communications, whereas bandwidth affects another region of the code with a few big messages.

In NEMO, results show that the simulated latencies and bandwidths only affect slightly to its execution time. However, it has data dependencies solved inefficiently and workload imbalances.

The last simulation performed to detect the slowest model due to coupling has revealed that IFS is slower than NEMO. Moreover, there is not enough bandwidth to transfer all the data in IFS, whereas in NEMO there is almost no contention.

This study is useful to improve the computational efficiency of the model, adapt it to support ultra-high resolution (UHR) experiments and future exascale supercomputers, and help code developers to design new algorithms more machine-independent.