1. Introduction

Background and motivation

- High-Performance Computing (HPC) developments: Ever-increasing performance and complexity (parallelization, vectorization, fast interconnects, parallel filesystems, memory hierarchies, etc.) – larger, more complex problems can be solved.
- Climate modeling developments: Higher resolution, multi-physics regional system models, growing model domains, long integration times and large ensembles.
- Multiple benefits of convection-permitting climate modeling (CPCM): e.g., reduced uncertainties related to convection parameterization, better representation of convective precipitation, more realistic representation of surface properties or exchange processes.
- CPCM is computationally demanding (Pan et al., 2015); however, HPC resources are in principle exist, e.g., at institutions like the Jülich Supercomputing Centre (JSC) (Tab. 1).

Objective – optimum model performance to allow extended large CPM runs.

- Use latest standard version of WRF (Skamarock et al., 2008) model for convection permitting simulations and optimize usage for simulations on JSC systems.
- Good performance target: 0.25 h wall-clock per simulated day, 30 yrs in about 3.75 months.

2. Experiments

Central European model domain, 480 x 456 x 50, n km, WRF v3.6.1 (Fig. 1a).
- Climate-mode settings: WSM5, RRTMG, YSU PBL, Noah LSM.

Pan-European model domain, 1600 x 1552 x 50, 3 km, WRF v3.5.1/3.8.1 (Fig. 1b).
- Simulations: Selected months, towards seasons and multi-year runs.
- Simulations: Climate-mode settings: WSM5/WSM6, CAM3/RRTMG, YSU PBL, Noah LSM.

3. Scaling tests

- Currently using highly scalable IBM BG/Q JUQUEEN (testing) and general purpose Linux cluster JURECA (production) (Fig. 2c). Reduce CPU-only setup, accelerators are not yet in use.
- 75% efficiency (speedup / ideal speedup) is considered a threshold for efficient code at JSC.
- On JUQUEEN (Fig. 2a), the 8192 MPI tasks run in about 3.5 times slower than the JURECA simulations (Fig. 2b), albeit the implementations can hardly be directly compared with each other.
- The production runs for the Central Europe domain are done with 10 nodes and 240 MPI tasks, requiring about 0.63 h/day (Fig. 2b).
- With 0.2951 h/day of the 3 km Pan-EU JURECA run with 3072 MPI tasks (Fig. 2c) and left and about 83% efficiency (Fig. 2b), the target is met, albeit with very large resource use of 128 compute nodes.
- Without using OpenMP/PMD hybrid parallelism, simulation moves from being compute bound to highly communication-bound (Elliot, 2015).
- A runtime improvement is expected from using GPUs or MICs; even if code does not run natively on the accelerator, by offloading e.g., the communication modules (incl. time-consuming data transfers between the CPU and the accelerator), more frequent calls to these routines may be possible within the performance penalty.

Input / Output operations (not shown)
- CPCM poses a big data challenge: data volume (up to +10 TB/month).
- Use of pNetCDF or task local NetCDF over serial I/O (Elliott, 2015).
- Use of VTune and Darshan for further analysis.
- CPCM poses a big data challenge: data volume (up to 10 TB/month).

4. Next steps

- Improvement of efficiency, use less resources.
- Use of hybrid parallelism in WRF (OpenMP/PMD) to reduce overhead in communication in combination with optimized thinning strategy in CPU-only and hybrid setups (Elliot, 2015).
- Optimum parallel I/O strategy.
- Systematic testing on JSC’s heterogeneous HPC architectures (CPUs GPU/MICs) based on the built-in functionalities (e.g., RRTMG target radiation scheme for GPU and MC).
- Detailed runtime performance profiling with Score-P/Scalasca, Vtune and Danaran.
- Testing in-in situ processing and visualization (Visit interface).
- Convection-permitting ready pre- and post-processing chains.
- Use of JUQUEEN’s NVIDIA accelerators through CUDA ported physical modules (e.g., for cloud microphysics, WSM5 (Meikin et al., 2012); or planetary boundary layer scheme (YSU) (Huang et al., 2015); multiple modules have been ported, e.g., by the Space Science and Engineering Center (SSEC) of University of Wisconsin-Madison.)

References


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