Project: **1040**

Project title: **ESiWACE: Scalability of Earth System Models**

Principal investigator: **Joachim Biercamp**

Report period: **2017-01-01 to 2017-12-31**

Allocation period: **2017-01-01 to 2017-12-31**

ICON-ECHAM Simulations: Scalability

Working towards the global high resolution simulations, we were able to set up for the first time a 1.2 km resolution grid (R2B11) for ICON simulations (in collaboration with Leonidas Linardakis, MPI-M). ICON simulations could be enabled at this high global resolution: we successfully ran ICON simulations of an aqua planet experiment (APE) using ECHAM physics on 1408 nodes of Mistral, compute2. Work was carried out in collaboration with Thorsten Mauritsen, MPI-M. In this context, the underlying APE experiment was used to analyse the performance of ICON at various resolutions, ranging from R2B4-R2B11 (resolutions spanning approx. 160-1.2km). The results and respective input scripts have been made available online in form of a performance benchmark[1]; see Figure 1 for strong scalability of a 5km global APE experiment.

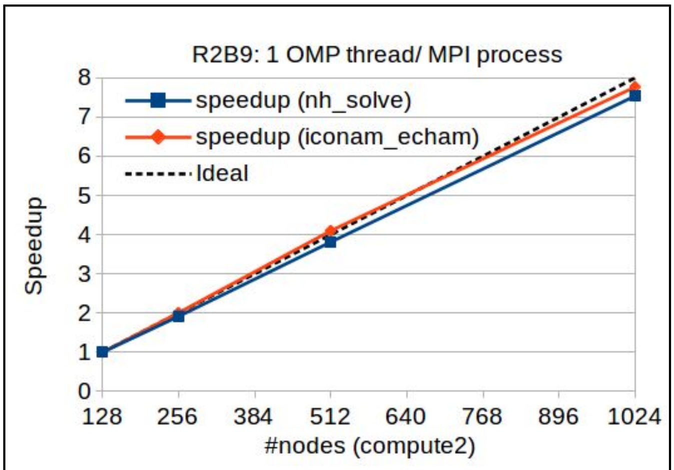

Figure 1: ICON R2B9 scalability of dynamical core and echam physics

ICON-NWP Simulations: Scalability

To drive ICON towards realistic global scenarios, focus was put in the following on the analysis of ICON including all relevant physical data (topography, complex initial conditions). For this purpose, a major challenge is constituted in I/O (which is very data-intensive) and the creation of initial and topographic data. For the first time, we were able to generate input data for globally resolved ICON simulations down to 2.5km resolution. The corresponding R2B10 ICON simulation was technically set up based on recent NWP scenarios that are studied by Matthias Brück, MPI-M, and Daniel Klocke, DWD (in collaboration with both scientists). The simulations were executed on Mistral, compute2 for 10 time steps to demonstrate its feasibility; however, instabilities occurred afterwards and could not be eliminated yet. Performance results suggest that an overall throughput (without I/O) of 13 forecast days/day should be achievable using 1024 nodes of Mistral, compute2. However, more considerations are required since latest R2B9 (5km resolution) experiments suggest the necessity of using smaller time steps than anticipated. For comparison with the IFS software (ECMWF), NWP simulations were carried out using R2B8/R2B9/R2B10 grids and 137/137/62 vertical levels. Although our

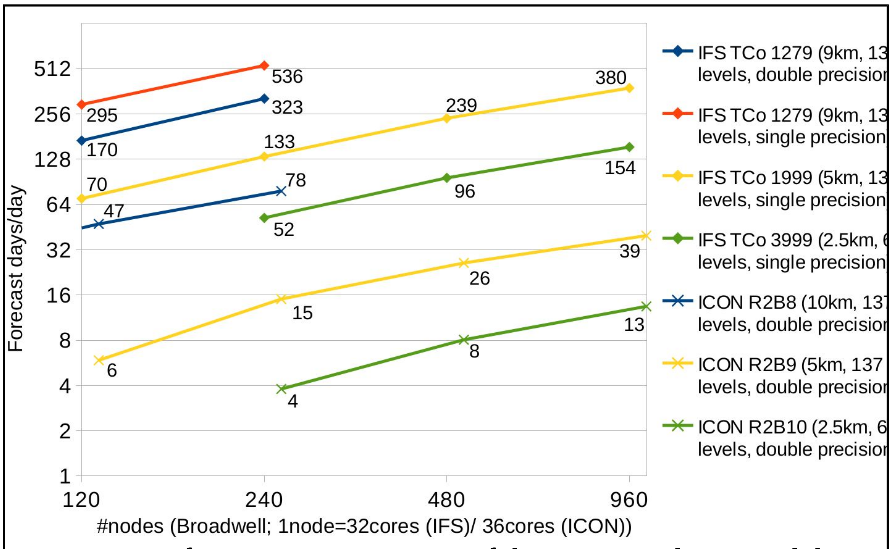

Figure 2: Performance comparison of the ICON and IFS model on Broadwell architectures

1 https://redmine.dkrz.de/projects/icon-benchmark/wiki/Instructions_on_download_execution_and_analysis_ICON_Benchmark_v160

simulations, cf. Figure 2, seem to be slower than IFS by factor of 10, some explanations for this could be identified (in exchange with experts from ECMWF):

- ICON is non-hydrostatic by construction, but IFS was executed in hydrostatic mode (~2x),
- several IFS experiments were carried out using single-precision only (~2x),
- IFS and ICON use different time stepping schemes, with IFS allowing for significantly larger time steps.

Based on this discussion, the observed performance is in alignment with the IFS studies. Besides, the use of large time steps as in IFS is still under discussion by experts with regard to physical soundness of evolving results.

ICON-NWP Simulations: Towards Production and Validation

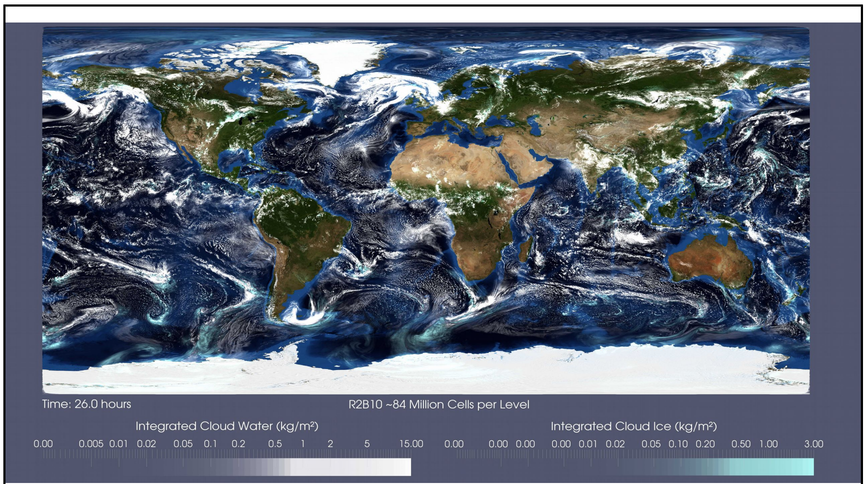

Figure 3: Visualisation of integrated cloud water and ice in a global R2B10 ICON-NWP simulation after 26h

The original plan in the extension period 07-12/2017 was to carry out further validation and scalability tests and to start working on coupled atmosphere-ocean systems. However, validation required significantly bigger amounts of compute time than anticipated. In this scope, a 3-week R2B9 (5km) global ICON-NWP simulation was established and was already partly analysed by Daniel Klocke, DWD, with regard to physical soundness of results. An animation of the simulation can be found on the website of ESiWACE[2] and has been used for dissemination purposes by Prof. Ludwig in a keynote talk at the Parco conference, 12-15 Sep 2017, Bologna, Italy; see Figure 3 for a comparable visualisation of a R2B10 (2.5km) run after 26h. A 3-day forecast using a 5km global resolution resulted in a run time of ca. 24h using 515 nodes of the partition compute2 of Mistral—the 3-week run thus already consumed (more than) the complete budget.

2 https://www.esiwace.eu/results/achievements