Project:	**852**
Project title:	**Diagnostics and ice clouds in ICON**
Project leader:	**Dr. Ulrike Burkhardt**
Report period:	**01.01.2014 – 31.12.2015**

1. HD(CP)² - S1 (Jöckel b302019, Kern b302040)

During the last two years, we designed and implemented a generalised interface structure in ICON (ICOsahedral Non-hydrostatic modelling framework; Zängl et al. 2015) and developed a prototype implementation of an advanced on-line diagnostic method. The diagnostic interface is based on the Modular Earth Submodel System (MESSy; Jöckel et al., 2005, 2010). The on-line diagnostic tool GRAGG (Grid AGGregation) provides the ability to aggregate native model variables of ICON on a coarse user-defined grid, which is used for sampling jPDFs (joint probability density functions) of ICON model variables chosen by the user. The main challenges during the development were the efficient utilisation of memory resources and the large communication demands between different MPI tasks. In addition, during the HD(CP)² project (http://hdcp2.eu/), colleagues at LMU (Ludwig-Maximilians-Universität, München) developed a satellite forward operator (VISOP – Visual Satellite Operator) utilising the diagnostic interface.

Computational resources on HLRE-2 ("Blizzard"), the HLRE-3 migration system, and HLRE-3 ("Mistral") were used for the optimisation of the diagnostic interface and the diagnostic tools regarding to performance and memory consumption, in order to derive a model system suitable for running the HD(CP)² final experiment.

The Figures show preliminary results of selected scaling experiments, conducted on "Mistral". We used an experiment setup with three nested domains with resolutions of 1,249m, 625m, and 312 m and 302,912, 893,548, and 224,132 grid cells, respectively, resulting in 1,420,592 grid cells in total. The vertical extend was 50 model levels and the LES physics package with a two moment microphysics was activated (Dipankar et al., 2015). The simulations were integrated over 1h simulation time, starting 24 April 2013, 00:00 UTC, with an integration time step of 10 s. We used 6 MPI tasks per node and 4 OpenMP threads per task and analysed model runtime utilising the timer mechanism already included in ICON. Values reported are for the timer "total". Maximum overhead introduced by the interface itself is 1.4% (with activated ICON output on 256 nodes). Un-optimised, we get an overhead increasing with number of cores for GRAGG from 6% to 32%, and decreasing with number of cores for VISOP from 11% to 5%. After optimisation – we parallelised the loops with OpenMP and reduced the calling frequency of the diagnostic submodels to their output times – the overhead decreased for the communication limited GRAGG ranging from 5.2% to 14.1%, and for the calculation limited VISOP ranging from 0.6% to 3.3% (Kern and Jöckel, in preparation for GMD(D)).

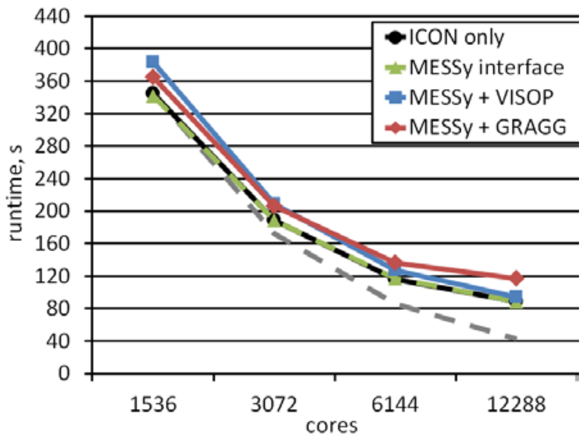

Figure 1 Runtime (s) for different testcases with deactivated output on 64, 128, 256, and 512 nodes (1536, 3072, 6144, and 12288 cores, respectively). The gray dashed line marks perfect scaling for the "ICON only" testcase.

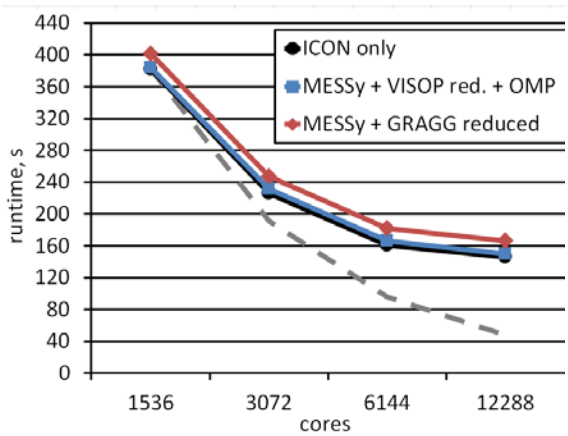

Figure 2 Comparison of the runtime (s) for "ICON only" and the optimised GRAGG and VISOP testcases. Output was activated in all testcases. The gray dashed line marks perfect scaling for the "ICON only" testcase with output activated.

We also integrated the additional diagnostic tools in the final HD(CP)² experiment setup and conducted first successful simulations. The experiment includes 3 nested domains over Germany, amounting in total of 32,222,392 grid cells and 150 model levels. This required especially the optimisation of the memory footprint of GRAGG and the inclusion of OpenMP.

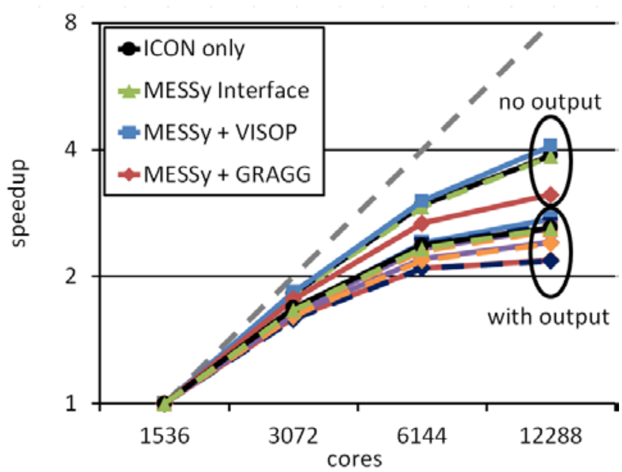

Figure 3 Speedup calculated to the baseline of 64 nodes for all testcases. The gray dashed line represents optimal speedup.

2. HD(CP)² - S3 (Burkhardt b309022)

During the last two years we designed, implemented and tested an ice cloud extension to the Tompkins cloud scheme Tompkins (2002) in the ICON-GCM. In order to describe the hysteresis of ice cloud cover (formation at high ice supersaturations and dissolution at ice saturation) (Kärcher and Burkhardt, 2008) we needed to introduce an additional prognostic variable, ice cloud cover. The introduction of the prognostic ice cloud cover means that the threshold relative humidity, from which on ice cloud cover exists, is not given any longer but needs to be calculated using the PDF of total water, on which the cloud scheme relies. The system of equations given by Tompkins (2002) can be only solved once an additional equation for the ice cloud cover is introduced. We have changed the code concerning the solution of the equation set in particular the iterative solution for the distribution bounds. One problem that we had to overcome is the fact that as soon as the moments of the PDF are changed, the microphysics cannot be calculated any longer without recalculating the humidity threshold of ice cloud cover which destroys the separation of the calculation of cloud cover, that is of the distribution bounds, and microphysics in two different routines.

Testing of the new parameterization uncovered a basic problem in the implementation of the cloud scheme within the leap frog time step. The time filter destroyed the consistency of the cloud variables with the thermodynamic variables and the calculation of a cloud cover that is supposed to be consistent with the microphysics of the time step before was only possible by making large corrections. Necessary corrections turned out to be of a similar order of magnitude than the physical tendencies themselves. A change of the time stepping scheme and the exclusion of the Tompkins cloud scheme within the ICON-GCM (introduced by MPI for Meteorology) changed the direction of our work.

We started this year with a new ICON-GCM, a pre-release version. We designed and implemented an ice cloud extension to the Sundqvist cloud scheme (Sundqvist et al., 1989) and started testing it. At the moment we are in the process of moving our ice cloud changes to the new ICON1.0.00 release.

We continue working on the ice cloud extension of the Sundqvist cloud scheme and we will get back to the Tompkins cloud scheme that is currently being re-implemented in ICON1.0.00.

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