BMBF Verbundprojekt

Report on DKRZ Resources in 2019

Executive Summary

The report summarizes the individual reports of projects associated to the project HD(CP)^2 (Highdefinition clouds and precipitation for advancing climate prediction). The reporting will cover the time period from 2019-01-01 to 2019-12-31. The individual project numbers are

- bm0834
- bm0838
- bm0852
- bm0974
- bm0982
- bm0994
- bm0999
- bb1018
- bm1027
- bm1032
- bb1041

The numbers for used computation time and used storage resources are taken as on 30 September 2019 unless stated otherwise.

The reports from the projects bb1041, bm1032, bm0999, bm974 and bm838 have to be understood as **final reports**, because the projects are not asking for computing time or storage resources in 2020.
It is agreed with the partners to move the core products of the individual projects to the /word and /arch storage space of account bm0834 to stay available for re-use in the community.

List of Content

1. Report Project bm834

Project title: HD(CP)2 module M, Cross-cutting Modelling Activities

Project lead: Björn Stevens, Rieke Heinze (MPI)

Panos Adamidis, Joachim Biercamp, Kerstin Fieg (DKRZ)

Reporting period: 01.01.2019 - 31.10.2019

	Allocated for 2019	Consumed (30.10)	Consumed in total
Computing time (node*h)	815.194	644.517	
Temporary storage /work (GiB)	1.260400	1.157.425	
Storage /arch (GB)	908.465	660.570	3.486.577
Long term storage /doku (GB)	110.000	3.367	115.440

For 2019 the WLA Block granted nearly 1.3 Mio node*h to the joint project HD(CP)2, which is about 20% of the total amount of computing time available for BMBF projects on *Mistral*. This reflects ambition of the HD(CP)2 Project of being one of the “Lighthouse projects” for the German Climate Research Community.

From this share, 62% of the computing time was assigned to subproject bm0834 (Modul M) and devoted to perform model runs of interest for the HD(CP)2 community of the domains DE, TA and NA. The remaining 38 % were distributed to the 10 other subprojects of the joint research project.

According to DKRZ policy the project management is allowed to shift resources between the projects of the joint project - when necessary and agreed by the subproject PIs. This led to multiple relocations of compute and storage resources from and to subproject bm0834.
In total, the WLA granted about 1.6 Mio GiB of Lustre /work temporary storage resources, 1.25 Mio GB of HPSS /arch storage and 158.237 GB HPSS doku to the HD(CP)2 joint project. The bm834 share counts for 1.26 Mio GiB Lustre work, 0.9 Mio GB HPSS arch and 110.000 GB long term storage HPSS /doku.

1.1 Experiments performed successfully at project account bm0834

I) DE - Domain

The following 4 days are computed and finalizes between Jan and Oct 2019 on *Mistral*:

Date	Notes
04.11.2015	default
06.11.2015	default
02.05.2013	With CCN concentration observed in 1985 but no interaction with radiation
27.06.2018	COSMO-D2 forcing
29.05.2016	Temporary and spatial high-resolution output for visualisation

We calculate 65000 node*h for a successful and complete simulation day, broken down into

- Simulation of the day: 60000 node*hours
- Reading input / Restart: 2500 node*hours
- Writing output (dependent on requirements) 2500 node*hours

Moreover we subsume approx. 3% of overhead for bug fixing, evaluation and preparation of setup and data.

Thus we used approximately 350.000 node*h for production, including 3% overhead for pre- and post processing.

II) NA – Domain

ICON-NWP limited area simulations: The simulation domain extends from 78W-40E, and from 23N-80N, and so also covers Europe and parts of North Africa. We have performed simulations with grid resolutions ranging from 80 km to 2.5 km, with 1-moment and 2-moment cloud microphysics, and with and without a convection parameterization.

With the model setup of ICON-NWP we simulated the experiment "transpose tAMIP" and repeated some of the days performed in 2018 after a bug fix.

ICON-LEM: The NAWDEX campaign was simulated with ICON-LEM.

III) TA – Domain

There were no days performed in 2019.
We allocated 200.000 node*h for experiments simulating the TA region, but the resources could not be used, because the scientist left the project.
Thus we used 190.474 node* h.

1.2 Summary: Resources used until 10/2019

Compute Resources

DE	350.000 Node*h
TA	-
NA	220.000 Node*h
Expired resources	130.000 Node*h
	600.000 Node*h

Storage resources

The Data Management Plan (DMP) (attached to the resource application document) describes in detail the amount of data stored for the individual experiments on */work* and */archive* resources.

1.3 Publications that use HD(CP)2 data in 2019

Acquistapace, C., U. Löhnert, M. Maahn, and P. Kollias (2019): A New Criterion to Improve Operational Drizzle Detection with Ground-Based Remote Sensing. *J. Atmos. Oceanic Technol.,* 36, 781–801, https://doi.org/10.1175/JTECH-D-18-0158.1

Lammert, A., A. Hansen, F. Ament, S. Crewell, G. Dick, V. Grützun, H. Klein-Baltink, V. Lehmann, A. Macke, B. Pospichal, W. Schubotz, P. Seifert, E. Stamnas, and B. Stevens (2019): A Standardized Atmospheric Measurement Data (SAMD) Archive for distributed cloud and precipitation process-oriented observations in Central Europe. *Bull. Amer. Meteor. Soc.,* 0, https://doi.org/10.1175/BAMS-D-18-0174.1

Montserrat Costa-Surós, Odran Sourdeval, Claudia Acquistapace, Holger Baars, Cintia Carbajal Henken, Christa Genz, Jonas Hesemann, Cristofer Jimenez, Marcel König, Jan Kretzschmar, Nils Madenach, Catrin Meyer, Roland Schrödner, Patric Seifert, Fabian Senf, Matthias Brueck, Guido Cioni, Jan Frederik Engels, Kerstin Fieg, Ksenia Gorges, Rieke Heinze, Pavan Kumar Siligam, Ulrike Burkhardt, Susanne Crewell, Corinna Hoose, Axel Seifert, Ina Tegen, and Johannes Quaas: Detection and attribution of aerosol-cloud interactions in large-domain large-eddy simulations with ICON. *Submitted to ACP*

Voigt, A., N. Albern, and G. Papavasileiou (2019): The atmospheric pathway of the cloud-radiative impact on the circulation response to global warming: important and uncertain. *J. Climate,* 32, https://doi.org/10.1175/JCLI-D-18-0810.1

2. Final Report Project bm838

Project title: HD(CP)2 – PDF cloud schemes
Project lead: Johannes Quaas
Reporting period: 01.01.2019 - 31.10.2019

This contribution to the HD(CP). project came to a successful completion. The major joint paper on the S1 – project (“Fast cloud adjustments to aerosol”) is now in Discussions (Costa-Surós et al., 2019). This paper documents how the aerosol perturbation imposed (1985 as peak-aerosol conditions for Central Europe vs. the control aerosol levels at the simulated date of 2 May 2013) is realistic in comparison to satellite- and ground-based remote sensing. A key result is reproduced as Fig. 1: It shows that also for the cloud droplet number concentration (Grosvenor et al., 2018) a clear detection-and-attribution is possible for the aerosol-induced perturbation, while for the cloud liquid water path, this is difficult.
Thanks to project 838, in particular now the ICON-LEM used in the HD(CP). project (Heinze et al., 2017) now contains well-tested and working model improvements and corrections, including the 4D-varying cloud condensation nuclei (CCN) concentrations, a radiation transfer scheme that digests the double-moment cloud microphysical information, and a sink due to the consumption of CCN at droplet activation (Costa-Surós et al. 2019).
Beyond this, current work investigates further the resolution-dependency of the aerosol-cloud adjustment results.

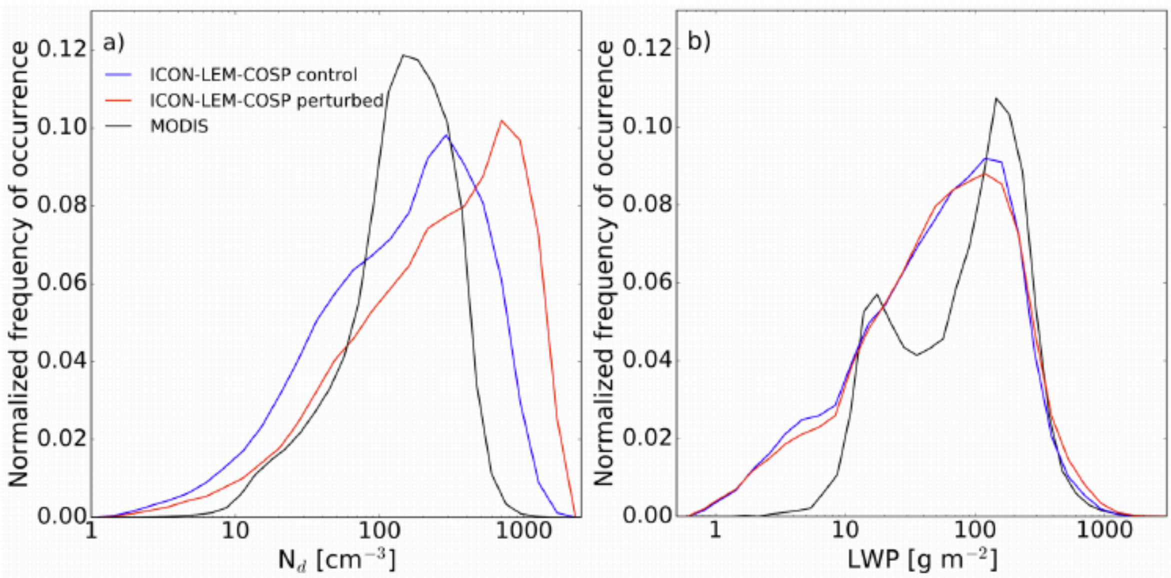

Figure 1: Normalized frequency of occurrence distributions computed from ICON-LEM (Heinze et al., 2017) including a satellite simulator. Data from the 2 May 2013 control (blue) and perturbed (red) simulations, matched with satellite observations from MODIS (black) obtained at the four satellite overpass times on the same day for a) cloud droplet concentration, N_d and b) liquid water path, LWP. From Costa- Surós et al. (2019).

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Costa-Surós, M., O. Sourdeval, C. Acquistapace, H. Baars, C. C. Henken, C. Genz, J. Hesemann, C. Jimenez, M. König, J. Kretzschmar, N. Madenach, C. I. Meyer, R. Schrödner, P. Seifert, F. Senf, M. Brueck, G. Cioni, J. F. Engels, K. Fieg, K. Gorges, R. Heinze, P. K. Siligam, U. Burkhardt, S. Crewell, C. Hoose, A. Seifert, I. Tegen, and J. Quaas, Detection and attribution of aerosol-cloud interactions in large-domain large-eddy simulations with ICON, Atmos. Chem. Phys. Discuss, in review, doi:10.5194/acp-2019-850, 2019.

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Heinze, R., A. Dipankar, C. C. Henken, C. Moseley, O. Sourdeval, S. Trömel, X. Xie, P. Adamidis, F. Ament, H. Baars, C. Barthlott, A. Behrendt, U. Blahak, S. Bley, S. Brdar, M. Brueck, S. Crewell, H. Deneke, P. D. Girolamo, R. Evaristo, J. Fischer, C. Frank, P. Friederichs, T. Göcke, K. Gorges, L. Hande, M. Hanke, A. Hansen, H.-C. Hege, C. Hoose, T. Jahns, N. Kalthoff, D. Klocke, S. Kneifel, P. Knippertz, A. Kuhn, T. Laar, A. Macke, V. Maurer, B. Mayer, C. I. Meyer, S. K. Muppa, R. A. J. Neggers, E. Orlandi, F. Pantillon, B. Pospichal, N. Röber, L. Scheck, A. Seifert, P. Seifert, F. Senf, P. Siligam, C. Simmer, S. Steinke, B. Stevens, K. Wapler, M. Weniger, V. Wulfmeyer, G. Zängl, D. Zhang, and J. Quaas, Large-eddy simulations over Germany using ICON: A comprehensive evaluation, Quart. J. Roy. Meteorol. Soc., 143, 69-100, doi:10.1002/qj.2947, 2017.

3. Report Project bm852

Project title: HD(CP)2 Diagnostics and ice clouds in ICON
Project lead: Dr. Ulrike Burkhardt
Reporting period: 01.01.2019 - 31.10.2019

HD(CP)² - S1 TP2 Kondensstreifenzirren (Burkhardt b309022, Verma b309131)

During the last computing period we have improved our contrail cirrus parameterization in ICON-LEM. We simulated contrail formation within natural cirrus and analyzed the results. We estimated the sublimation of the entrained natural cirrus ice crystals during the contrail's vortex phase and their effect on the ice supersaturation within the vortex and the survival fraction of nucleated contrail ice crystals. Fig. 1 is comparing cloud properties with those properties that would be able to change the survival rate significantly. The simulated natural cloud (green points) is optically thin and cannot make significant change in the survival fraction of contrail ice crystals. On the other hand, the same natural cloud polluted by aged contrail ice crystals (red points) can change the survival fraction of contrail ice crystals.

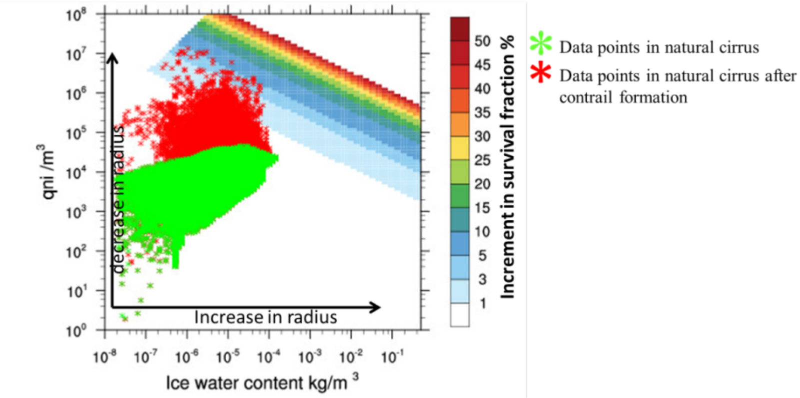

Fig. 1: *Properties of a natural cloud (green) and of the same cloud which is already modified due to air traffic (red) and change in the survival rate of ice crystals during the vortex phase in %.*

We simulated the life cycle of contrails within natural clouds and their impact on microphysical processes. The evolution of the size distribution of the ice crystals after contrail formation within a natural cloud is shown in fig.2. Initially, many small ice crystals are formed within the contrail (Fig. 2(a)). Later, contrails dilute and ice crystals grow in size, so that the peak at small ice crystal sizes is shifted towards larger sizes (Fig. 2(b) and 2(c)). Even 6 hours after formation, a large number of small ice particles is visible in the contrail polluted cloud (Fig.2(c)).

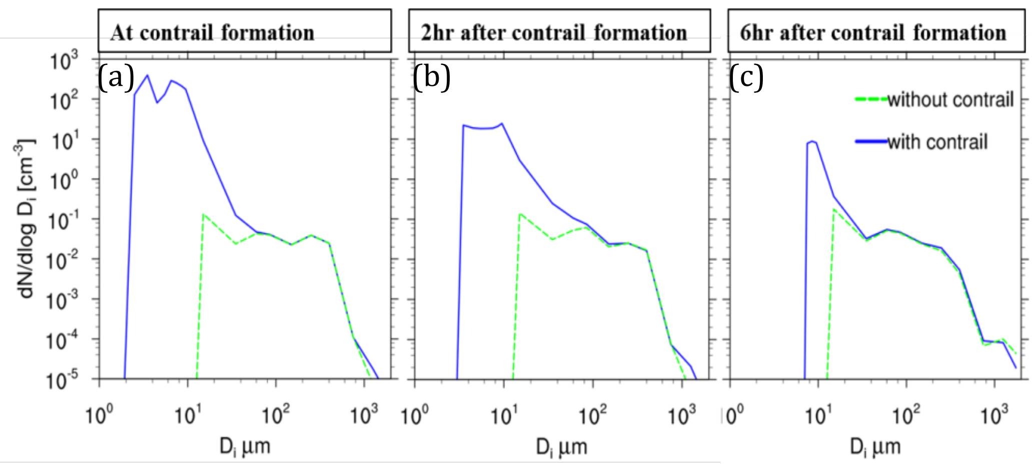

Fig. 2: *temporal evolution of the ice crystal size distribution of a cloud perturbed by contrail formation (blue) and a control simulation (green) at (a) contrail formation, (b) after 2 hr and (c) after 6 hr.*

We have performed a longer simulation using a flight inventory. Many contrails form within the large scale cloud deck. About 1.5 hours after the start of air traffic a large fraction of the natural cloud is perturbed due to contrail formation (Fig. 4). The ice crystal number concentration has increased within the cloud significantly. Aged contrails are diluted and distributed horizontally and vertically (Fig. 4(b)). In a few locations the cloud is dissolved (top left side of the cloud in fig. 4(b)) when compared to the undisturbed cloud (fig. 4c). This appears to be due to the smaller ice crystal sizes in combination with fluctuations in relative humidity. We are currently analyzing the impact of the contrail perturbations on the optical depth of the cloud and its temporal development.

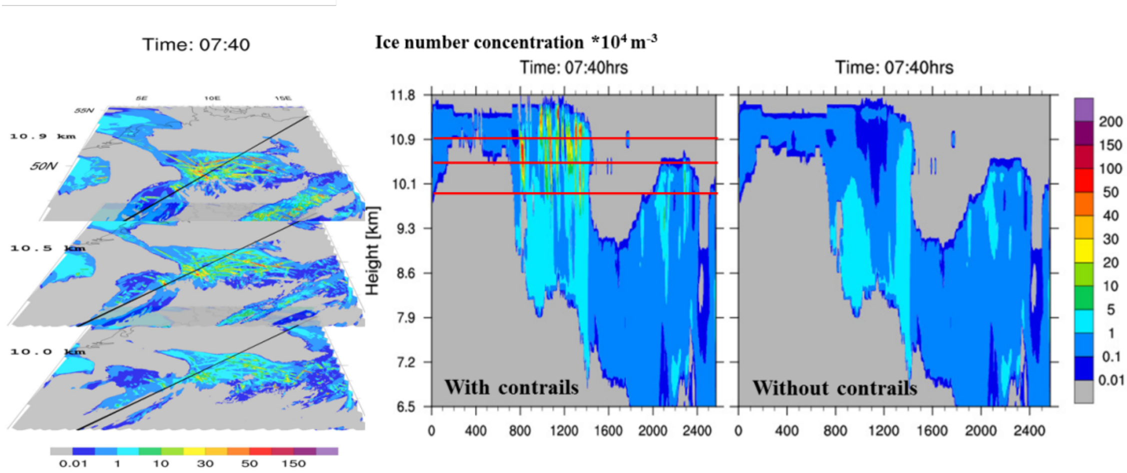

Fig. 4: *(a) horizontal view of a cloud layer perturbed by air traffic at three different heights e.g. 10.9 km, 10.5 km and at 10.0 km about 1.5 hr after the start of air traffic and (b) vertical slice of the cloud along the black diagonal line in plot (a) and (c) vertical slice of the same cloud without contrail formation. In (b) and (c) the x-axis gives the number of grid boxes along the black line.*

Significantly less computing time was used than planned. This was due to the fact that our model parameterization was based on an older model version which would not start from the restart files produced by the high resolution HD(CP)2 simulations. Therefore, we could not make simulations starting from specially selected atmospheric situations as planned. Support for merging our parameterization into a newer ICON-LEM version was only available after a few months so that computing time was lost.

The next steps will be, on the one hand, to merge our contrail parameterization scheme into the ICON_LEM main branch in order to enable long simulations with three nested domains for different synoptic situations. Those simulations will enable an evaluation of our contrail parameterization with observations. On the other hand, we plan to perform simulations of specially selected situations in order to analyze more life cycles of contrail perturbations in natural clouds and in order to obtain a better statistic.

HD(CP)² - S3 TP4 Einfluss von Konvektion auf Zirrusbewölkung und das Wasserbudget der oberen Troposphäre (Burkhardt b309022, Arka b309120)

During the last computing time period we contributed to the HD(CP)2 publications on the performance of the ICON-LEM in general (Stevens et al.) and in particular in convective situations (Rybka et al.) and on the impact of increased CNN concentrations (Costa Suros et al.). This meant that we concentrated on analyzing high resolution simulations using the pp-Nodes. Furthermore, we continued our work on improving the Tompkins cloud parameterization in the ICON-GCM, analyzing the sub-grid scale variability of total water and its temporal evolution in the high resolution ICON-LEM simulations. We analyzed convective situations regarding changes in total water and connected changes in the skewness of the PDF of total water (Fig. 5) in order to infer a skewness tendency that can be used in the GCM. The analysis suggests that the expected increase in skewness with convective input holds only for low cloud coverage and that skewness decreases again with increasing cloud cover.

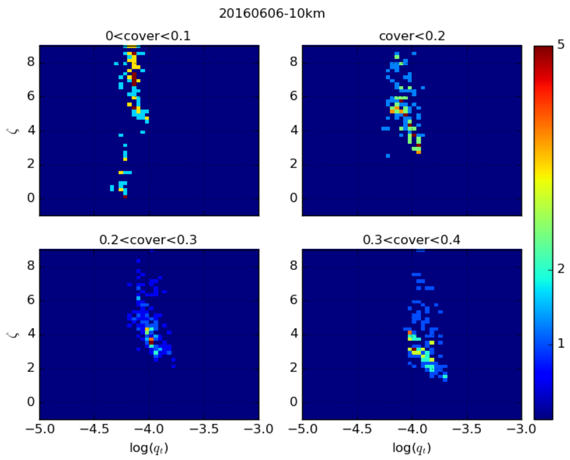

Fig. 5: *Skewness of the total water PDF dependent on total water on the 6th of June 2016, a day with many scatter convective systems at 10km height.(left top) for low cirrus cover <0.1, (right top) for 0.1< cirrus cover <0.2, (left bottom) for 0.2 < cirrus cover <0.3 and (right bottom for higher cirrus cover.*

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Costa-Surós, M. et al - Detection and attribution of aerosol-cloud interactions in large-domain large-eddy simulations with ICON, in review.

Rybka, H., Köhler, M., Seifert, A., Burkhardt, U., Arka, I., Bugliaro, L., Reichardt, J., Görsdorf, U., Meyer, C., Strandgren, J., Horvath, A. - High-resolution modeling of high-CAPE summer convection -role of ice microphysics and large-scale forcing, in preparation.

4. Final Report Project bm974

Project title: HD(CP)2 Module S5 (Clouds and convective organization)
Project lead: Rieke Heinze
Reporting period: 01.01.2019 - 31.10.2019

Granted computation time for 2019: 100.00 node*h
Used computation time for 2019: 76.343 node*h
Granted storage on Lustre (/work): 60.000 GiB
Granted storage on HPSS (/arch): 50.000 GB
Granted storage on HPSS (/doku): 5.000 GB

One of the main uncertainties within climate projections using general circulation models is the representation of low level/boundary layer clouds and their feedback with the turbulence (Nuijens et al., 2015). One way to improve the representation of these low level clouds in NWP (numerical weather prediction) models is through turbulence parameterization (Bony and Dufresne, 2005). A good knowledge of higher-order moments of turbulence is fundamental for the improvement of boundary layer parameterization schemes in NWP and climate models, especially for cloud topped cases. During the reporting period, we analyzed the second and third moments and corresponding budget equations of various turbulent quantities using idealized high resolution large eddy simulations of different cloud topped boundary layer cases such as BOMEX (the Barbados Oceanographic Meteorological Experiment), ARM (Atmospheric Radiation Measurement), RICO (Rain in Cumulus over the Ocean) and DYCOMS (the DYnamics and Chemistry Of Marine Stratocumulus experiment). The simulations were performed using the LES model, MicroHH (van Heerwaarden et al., 2017). Since the DYCOMS case was available only in MicroHH2, we implemented the second and third order budget terms of turbulent moments in MicroHH2 version and tested the implementation on MISTRAL. In order to examine the importance of grid resolution on the budget analysis of higher order moments, we carried out different sensitivity studies with distinct mesh sizes using the BOMEX case. Vertical profiles of different higher order moments and corresponding budget equations were analyzed and the relative importance of various terms in maintaining the budgets was examined. The study underlines the importance of pressure terms in the flux budget of scalar quantities (Figure 1). They act as the major source or sink terms in the second and third order (not shown) flux budgets, especially in the cloud layer. Overall the study provided useful information for the better representation of cloud topped, non-precipitating and precipitating boundary layers in the turbulence parameterization. Currently a manuscript is under preparation.

3D radiative effects were shown to have an impact on cloud development in high resolution (large eddy) simulations. Temporal interaction of high resolved clouds and realistic (3D) heating and cooling rates in the solar and thermal spectral range can cause differences in cloud field organization, e.g. promoting the formation of cloud streets (Jakub and Mayer, 2017), or leading to cell-structures and clustering (Klinger et al., 2017). Apart from the heating and cooling rates, the neglect of horizontal transport of radiation leads to localized errors and biases in the surface radiative flux and atmospheric heating rates. One example is shown in Figure 2. Here we calculate solar downwelling radiation based on liquid and ice water of the ICON-LEM DOM3 (2014-07-29 12:02:30Z) domain with 1D and the new 3D radiative transfer approximations and compare it to a 3D benchmark MonteCarlo model which uses the native unstructured mesh of ICON-LEM. The simulations were performed with a constant surface albedo (A = 0.1) and the sun is positioned at a zenith angle of 60◦. Mistral computing was used to develop, test and benchmark the new 3D radiative transfer scheme for ICON-NWP and ICON-LEM. Particularly the development of robust and scalable parallel matrix solvers needed to be done on representative machines with a strong network architecture. A scientific publication will present the technical aspects and results and is planned in the beginning of 2020.

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Jakub, F. and Mayer, B.: The role of 1-D and 3-D radiative heating in the organization of shallow cumulus convection and the formation of cloud streets, Atmos. Chem. Phys., 17, 13317–13327, https://doi.org/10.5194/acp-17-13317-2017, 2017.

Klinger, C., Mayer, B., Jakub, F., Zinner, T., Park, S.-B., and Gentine, P.: Effects of 3-D thermal radiation on the development of a shallow cumulus cloud field, Atmos. Chem. Phys., 17, 5477–5500, https://doi.org/10.5194/acp-17-5477-2017, 2017.

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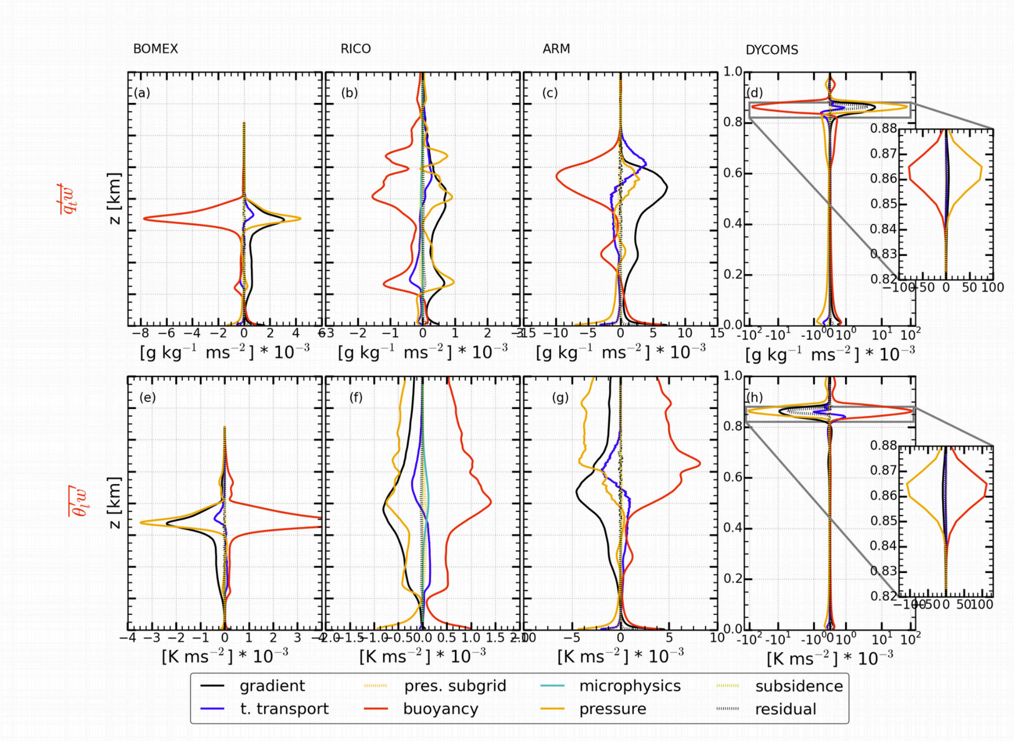

Figure 1: Budget terms of vertical flux of specific humidity and liquid water potential temperature for four idealized boundary layer cases.

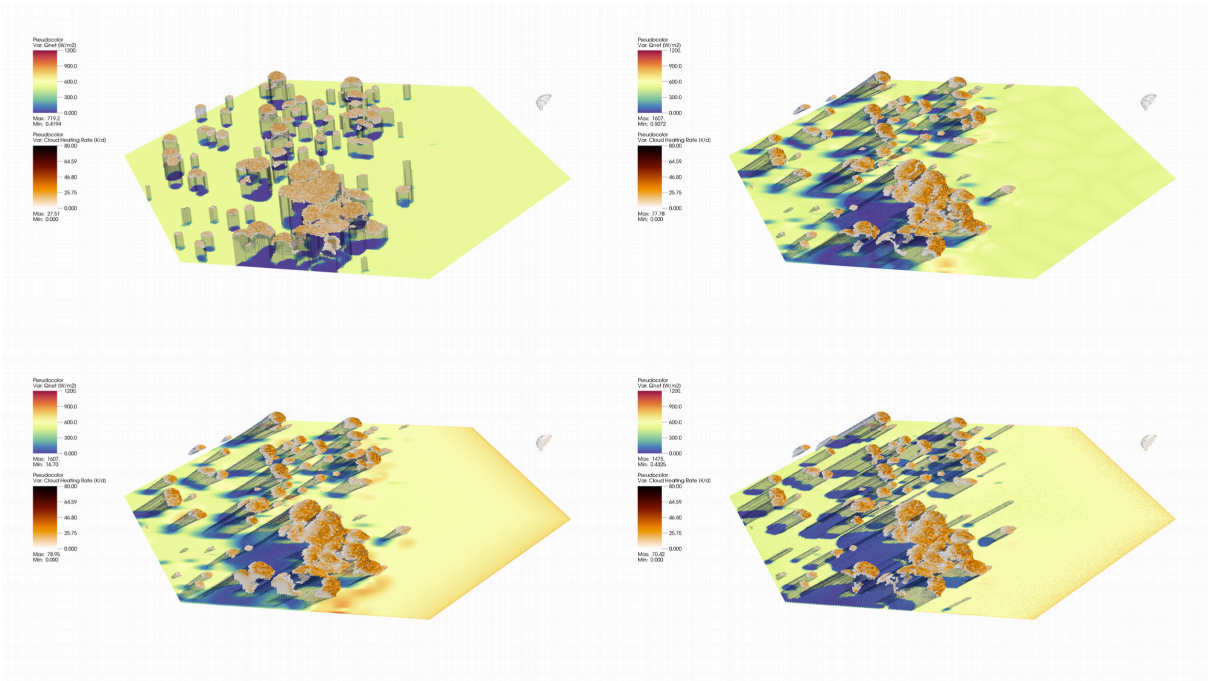

Figure 2: Snapshot of atmospheric heating rates and downward surface irradiance from a HDCP2 simulation with ICON-LEM (DOM3, dx~150m, domain-cutout around Berlin area). Upper panel shows simulations with boundary conditions as imposed in e.g. ICON-LEM where we assume that the atmosphere outside of the domain goes on infinitely with the local optical properties at the boundary elements. On the top left the results with a delta-edddington twostream solution as it is traditionally employed in NWP and LES models and on the right the solution with the unstructured mesh variant of the TenStream solver. At the bottom we show the results for the same scene with open boundary conditions (vacuum outside of the domain) and compare the TenStream solution to a benchmark MonteCarlo simulation (validated against MYSTIC) which traverses the native mesh.

5. Report Project bm982

Project title: HD(CP)2-II S4 (Land Surface Heterogeneity)
Project lead: Christopher Moseley
Reporting period: 01.01.2019 - 31.10.2019

Resources at DKRZ have been requested for 2019 for the project S4 in Phase II of HD(CP)² for simulations investigating land surface heterogeneities. In detail simulations were planned to investigate the unresolved processes of land-surface heterogeneity and its feedback to the planetary boundary layer including cloud development and convection initiation.

For 2019, an amount of 257277 node hours was granted for DKRZ project bm0982 for the use of S4. The simulations performed in the report period on this computing account can be divided into different analysis branches:

(A) Idealized simulations with different ICON-NWP and LEM configuration

1. In the beginning of 2019, systematical differences in the energy balance of the planetary boundary layer of ICON-LEM and ICON-NWP were observed. The ICON-NWP setup showed systematically colder boundary layer. To find the source of the systemically colder boundary layer in ICON-NWP in comparison to the ICON-LEM simulation, idealized ICON simulations with constant energy surface fluxes as the lower boundary condition are performed.
2. In order to investigate the dynamical effect of land surface heterogeneity, idealized ICON simulations with stripe-wise land heterogeneity are performed for different types of convection with several grid spacings within the turbulent grey zone. At grid spacings typically used in operational weather forecasting, model-induced artificial circulations have been generated which act as a possible trigger mechanism for cloud and precipitation formation. The results of this study suggest that the effects of land surface heterogeneity are overestimated in the kilometer range.
3. Idealized ICON-LEM simulations with a spatial variation of soil moisture were performed. The variability in soil moisture showed to have an influence on the surface energy fluxes in the planetary boundary layer and the induces secondary circulations, as well as they influence the development of clouds.

(B) Idealized simulations with PALM

4. Very high resolution idealized simulations on deca-meter scale with the model PALM were performed to proof the validity of the Monin-Obukhov Similarity-Theory (MOST) over heterogeneous terrain. The high-resolution large-eddy simulations showed the validity of MOST in heterogeneous subsurfaces under the condition that turbulence production is dominated by shear. In convective situations, deviations from homogeneous to heterogeneous subsurface become apparent.

(C) Real case studies

5. ICON-LEM simulations were set-up and performed over the southern great plains in the united states of america covering a horizontal resolution from 5 km to 150 m forced by IFS-data. The results are compared with observations.
6. Several runs with ICON were performed over Germany covering a horizontal grid spacing from 5 km down to 150 m in order to investigate the effect of grid spacing on convection initialization and evolution. Simulations for different synoptic conditions

revealed that the beginning and the sum of the precipitation vary with the grid resolution. In addition to that it was observed that the initialization of the precipitation starts earlier for the LES scheme than for the NWP scheme. It could be shown that the effect of land surface resolution is smaller compared to the one of the model grid resolution.

Justification of shifted computing time:

- 29181 node hours expired in March 2019 as the focus was set to idealized simulations which needed less computational time in the beginning of the reported period. These idealized simulations were set up to investigate systematical differences in the energy balance of the planetary boundary layer of ICON-LEM and ICON-NWP observed in the beginning of 2019. ICON-NWP showed systematically colder boundary layer. Idealized ICON simulations with constant energy surface fluxes reveal the source of the above mentioned differences. In summer 2019, the reason for the differences was found to be in the coupling of the ICON-NWP turbulence parameterization scheme with the ICON dynamics. In the second quarter, 526 node hour expired due to unexpected long down time on mistral. In the third quarter of 2018 no computing time expired.

Overview

Granted computation time for 2019: 257277
Granted storage on Lustre (/work): 80000
Granted storage on HPSS (/arch): 75000
Granted storage on HPSS (/doku): 5000

6. Report Project bm994

Project title: HD(CP)2, S3, TP2
Project lead: Peter Spichtinger
Reporting period: 01.01.2019 - 31.10.2019

Allocated computation time for 2019: 10000 Node hours
Allocated storage on Lustre (/work): 7500 GiB
Allocated storage on HPSS (/arch): 5500 GB
Allocated storage on HPSS (/doku): 0 GB

1. What was this computation time used for?

We performed ICON-LEM simulations with the 2-moment ice mode microphysics scheme of two WCB case studies utilizing two set-ups. A grid 13 km horizontal resolution was used to perform sensitivity studies for a range of various microphysical parameterizations. For the production run we performed the simulation on a 2.5 km resolution grid to resolve deep convection and investigate the effect of a finer spatial resolution on ice formation pathways, where we were particular interested in a better representation of homogeneous nucleation. The trajectory tool LAGRANTO was used to track the evolution of cloud properties along the WCB. Further, statistical analysis of microphysical parameters both within the domain and along the WCB provided insight on the impact of the various ice formation pathways on the cloud and the interplay of in-situ and liquid origin formation.

2. Where there deviations from the schedule? Why and why was this necessary? What was done instead?

We implemented and tested additional secondary ice formation mechanisms (droplet shattering and collisional break-up) for the ICON ice modes scheme which required only marginal computing time. Unfortunately, in preparation for our second case study we encountered technical difficulties with retrieving and interpolating IFS analyses data, which delayed the simulation run until the following allocation period.

3. Publications (also submitted and in review) that use data that was gained during 2019.

They are two publications in preparation: a model paper on the ice modes microphysics scheme and a paper investigating in-situ vs. liquid origin ice formation pathways for a WCB case

7. Final Report Project bm999

Project title: Cross – Cutting Observational Activities
Project lead: Andrea Lammert
Reporting period: 01.01.2019 - 31.10.2019

The project 999 was part of the HD(CP)² project. The applied Swift Object Storage was used in the process of the long term archiving of the HD(CP)² observational data into the WDCC. The HD(CP)² Observation Prototype Experiment HOPE, with the second part HOPE-Melpitz, as well es a short term intensive observation period (IOP) in Lindenberg (the experiment are now in the DOI process) are now available at:
https://cera-www.dkrz.de/WDCC/ui/cerasearch/entry?acronym=HDCP2-OBS_HOPE
https://cera-www.dkrz.de/WDCC/ui/cerasearch/entry?acronym=HDCP2-OBS_HOPE-Melpitz
https://cera-www.dkrz.de/WDCC/ui/cerasearch/entry?acronym=HDCP2-OBS_IOP-Lindenberg.

Thus, project 999 could be closed successful.

8. Report Project bm1018

Project title: HD(CP)2 S6 Cloud-radiative interactions with the North-Atlantic storm track
Project lead: Aiko Voigt
Reporting period: 01.01.2019 - 31.10.2019

Consumed computation time 2019: 18,300 Nh (as of 15 Oct 2019)
Allocated storage on Lustre (/work): 24,000 GB, used 17,000 GB (as of Oct 15 2019)
Allocated storage on HPSS (/arch): 48,000 GB, used 40,000 GB (as of Oct 15 2019)
Allocated storage on HPSS (/doku): 3,000 GB, used 0 GB (as of Oct 15, 2019)

1. What was this computation time used for?

In 2019, we performed global simulations with the atmosphere component of ICON-NWP in a present-day setup (e.g., with continents, sea ice and a seasonal cycle) and with prescribed sea surface temperatures. We used model version 2.1.00 and ran the model in R2B4 horizontal resolution with 47 vertical levels. In the simulations, we applied the cloud-locking method to determine the impact of regional cloud-radiative changes on the response of the midlatitude circulation (i.e. the eddy-driven jet streams and storm tracks) to global warming. These simulations complement our simulations from 2017 and 2018 in which we investigated the impact of global cloud-radiative changes on the circulation response. We performed simulations to investigate the impact of cloud-radiative changes in:

- The tropics (30°S-30°N)
- The midlatitudes (30°N-60°N and 30°S-60°S)
- The polar regions (60°N-90°N and 60°S-90°S)
- The Maritime Continent and western tropical Pacific (24°S-24°N, 78°E-152°W)
- The North Atlantic (26°N-74°N, 60°W-0°)
- Everywhere except over the Maritime Continent/western tropical Pacific and North Atlantic

For each region, we performed four simulations with a length of 30 years each. Consumption:
14,000 Nh; 7,600 GB of work; 40,000 GB of arch.

We have used the Lagranto tool to compute Lagrangian trajectories of warm conveyor belts for the limited-area ICON-NWP NAWDEX simulations of cyclone Vladiana performed within bm0834 (Sep 23, 2016; resolutions from 80 km to 2.5 km). The Lagrangian trajectories are used to understand how resolution, cloud microphyics and convection impact diabatic processes within a warm conveyor belt. A paper on these results is currently in preparation (Choudhary and Voigt, 2019, in prep.). **Consumption: 2,500 Nh.**

We have further performed ICON-NWP simulations studying the effect of cloud-radiative heating and other diabatic processes on NAO variability on timescales of 5-10 days. We used the model version of ICON-2.1.00 in resolution R2B4 with 47 vertical levels and prescribed SST. These simulations consist of 5 members initialized from 5 different initial states (November 1) that we run them for 5 months (untill March 31). This provided us with 25 control forecasts for the period of November-March. We then applied an external diabatic temperature tendency derived from NAO regression and re-ran these simulations by performing short-term 10-day forecasts. These simulations are currently analyzed and will contribute to a paper that is in preparation (Papavasileiou, Voigt, Knippertz, Simpson, Medeiros, 2019, in preparation). **Consumption: 1,800 Nh; 9,100 GB of work.**

In the last quarter of 2019, we will continue to test various patterns of external diabatic temperature tendency in the ICON-NWP model. In these simulations we will test the sensitivity of the NAO variability to the imposed external diabatic heating pattern. **Estimated consumption in 2019Q4: 3,000 Nh.**

2. Where there deviations from the schedule? Why and why was this necessary? What was done instead?

We have decided to focus on the ICON-NWP version with fixed SST (originally, we had planned to perform simulations with a slab-ocean extension of ICON-NWP). The reason for this was that we wanted to focus on the atmospheric pathway of the cloud-radiative impact and to understand the impact of regional cloud changes. The surface pathway, for which a slab ocean would be needed, is interesting as well but was studied by others before. Instead, the regional components of the atmospheric pathaway have not been studied before for realistic boundary conditions (only for aquaplanet).

For 2019 we originally had planned to perform locked cloud simulations to study the NAO variability. Yet, our observational analysis of cloud impacts on NAO variability let us to revise our simulation strategy. Instead of locked simulations, we decided to use the short term forecasts approach in combination with a prescribed additional heating pattern. This strategy is easier to interpret, easier to perform and computationally cheaper.

Despite these slight necessary changes, we are on good schedule to use our allocated resources until the end of 2019. For Q42019, we plan to archive those simulations currently stored on work, so that we will also have used our allocated archive space (and docu space) before the end of 2019.

3. Publications (also submitted and in review) that use data that was gained during 2019.

Albern, N., A. Voigt, and J. G. Pinto (2019): Cloud-radiative impact on the regional responses of the midlatitude jet streams and storm tracks to global warming. Journal of Advances in Modeling Earth Systems, 11, 1940–1958. https://doi.org/10.1029/2018MS001592.
Choudhary, A. and A. Voigt (2019), Cloud-diabatic processes in a warm conveyor belt: impact of model resolution, cloud microphysics and convection, in preparation.

Voigt, A., Albern, N., and Papavasileiou, G. (2019): The Atmospheric Pathway of the Cloud-Radiative Impact on the Circulation Response to Global Warming: Important and Uncertain. J.Climate, 32, 3051–3067. https://doi.org/10.1175/JCLI-D-18-0810.1

Papavasileiou, G., Voigt, A., Knippertz, P., Simpson, I., Medeiros, B. (2019): The role of cloudradiative effects and diabatic processes for short-term dynamics of the North Atlantic Oscillation, in preparation.

9. Report Project bm1027

Project title: HD(CP)2 S1 TP4: Cloud adjust
Project lead: Corinna Hoose
Reporting period: 01.01.2019 - 31.10.2019

Consumed computation time 2019: 1 CPUh (but spread out over 1/2019-9/2019)
Allocated storage on Lustre (/work): 5000 GiB, used: 386 GiB
Allocated storage on HPSS (/arch): -
Allocated storage on HPSS (/doku): -

1. What was this computation time used for?

We have used the computation time for postprocessing, analysis and visualization of data from the large HD(CP)2 simulations, in particular an analysis of the microphysical process rates via a newly developed recalculation method, an analysis of the effect of CCN doubling on hydrometeor concentrations, and comparison to satellite data.

2. Where there deviations from the schedule? Why and why was this necessary? What was done instead?

The project HD(CP)2_S1_TP4 has been extended by 12 months. The PhD thesis of Jonas Hesemann is planned to be submitted in fall 2020.

3. Publications (also submitted and in review) that use data that was gained during 2019.

Montserrat Costa-Surós, Odran Sourdeval, Claudia Acquistapace, Holger Baars, Cintia Carbajal Henken, Christa Genz, Jonas Hesemann, Cristofer Jimenez, Marcel König, Jan Kretzschmar, Nils Madenach, Catrin I. Meyer, Roland Schrödner, Patric Seifert, Fabian Senf, Matthias Brueck, Guido Cioni, Jan Frederik Engels, Kerstin Fieg, Ksenia Gorges, Rieke Heinze, Pavan Kumar Siligam, Ulrike Burkhardt, Susanne Crewell, Corinna Hoose, Axel Seifert, Ina Tegen, and Johannes Quaas: Detection and attribution of aerosol-cloud interactions in large-domain large-eddy simulations with ICON. Manuscript submitted to Atmos. Chem. Phys. Disc.

Two more peer-reviewed publications are still in preparation.

10. Final Report Project bm1032

Project title: HD(CP)2 sensitivity of convection – high resolution ensemble simulations
Project lead: Martin Köhler
Reporting period: 01.01.2019 - 31.10.2019

Evaluation of ice and cloud water content in ICON-LEM, ICON-NWP and ICON-GCM has been performed using satellite observations. This comparison was based on only one high-resolution simulation with ICON-LEM (covering grid spacings on different domains between 156m to 625m and spanning a time period of 48 hours) and multiple low resolution runs with parameterized physics starting with different initial conditions. The analysis demonstrated that ICON-LEM forecasts could in principle reproduce the main meteorological evolution on these convective days (isolated and organized convection; developing of cirrus anvil clouds). On closer consideration cloud formation sometimes occur with an offset in time. Furthermore the model behavior is dependent on the embedded domains in ICON-LEM.

ICON-LEM simulations were performed for two specified days with different initial and lateral boundary conditions to investigate the model sensitivity. Initial and boundary data from IFS, the operational ICON weather forecasts from DWD and COSOM were used for these forecasts. All runs were performed with a lower ICON-LEM resolution of 625m.

These runs were then evaluated concerning horizontal and vertical distribution of ice water content and cloud occurrence. Satellite and ground based observations were used to investigate the model performance with respect to the selected initial conditions.

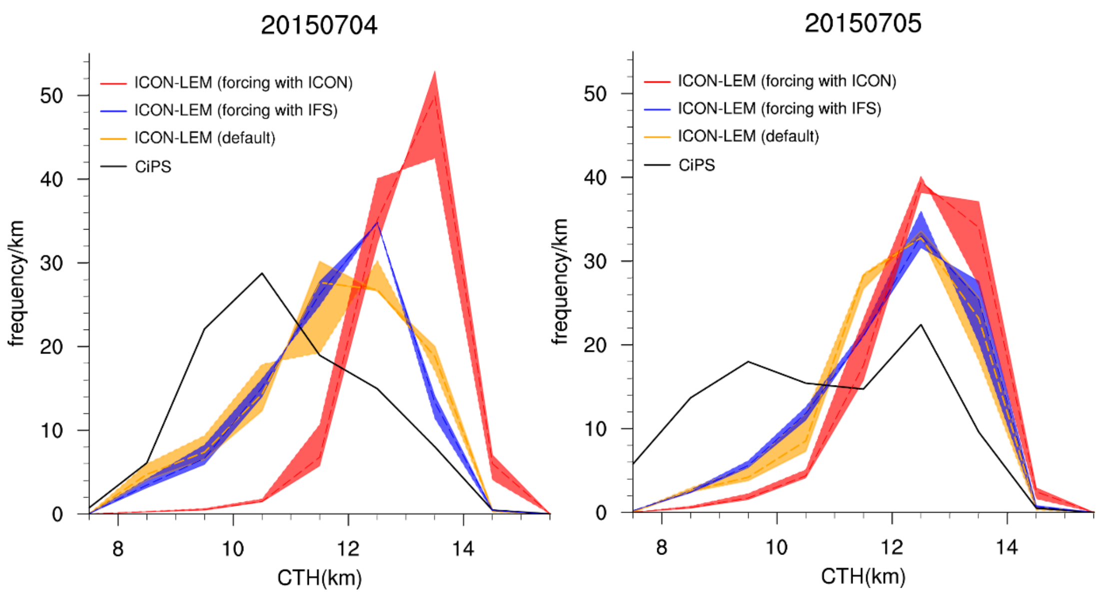

Figure 1. Change in cloud top height distribution when varying the initial and boundary conditions for the 4th (left) and 5th (right) of July 2015. Red, blue and yellow lines correspond to forcing data from ICON, IFS and COSMO. Observations from CiPS are added for reference (Cirrus Properties from MSG/SEVIRI).

Figure 1 shows the change in cloud top height distribution when varying the initial and boundary conditions for the 4th and 5th of July 2015 using forcing data from ICON, IFS and COSMO. Comparted to observations from CiPS (Cirrus Properties from MSG/SEVIRI). These two days were specifically selected as an extreme "explosive" summertime convective event. Given the large CAPE leading to convection at unpredictable locations the ICON-LEM simulations for that period depends largely on the forcing dataset.

As a last evaluation, the lower cloud limit was evaluated in these simulations and compared using the 155 DWD ceilometer station data. Figure 2 shows the distribution of the cloud base for three periods during the diurnal cycle (upper panel) and the daytime evolution of the cloud base (lower panel).

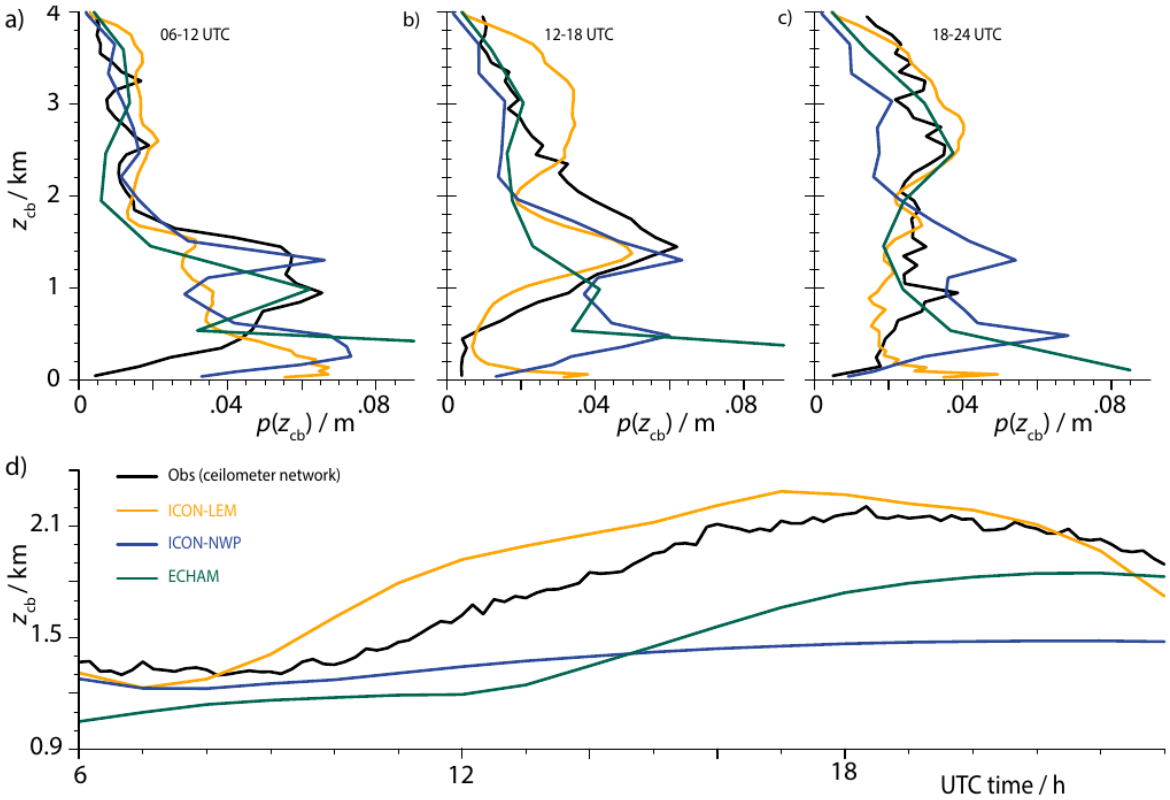

Figure 2: Distribution of cloud base in three parts of the diurnal cycle (a-c) and the mean evolution of cloud base (d) for ICON-LEM, ICON-NWP and ECHAM as compared to 155 ceilometer stations over Germany.

In general, there is also a highly improved representation of cloud base by ICON-LEM, in particular the evolution of the planetary boundary layer. The diurnal cycle is better described, especially the cloud base height from 12 UTC, which goes along with the improved representation of clouds above 2 km. The results of cloud profiles and the comparisons of the cloud base went into the publication by Stevens et al., 2019.

References

Stevens, B., and HDCP2 - Added Value Team, Journal of the Meteorological Society of Japan, Large-eddy and storm resolving models for Climate Prediction - The Added Value for Clouds and Precipitation 2019, in review.

Rybka, H., Köhler, M., Seifert, A., Burkhardt, U., Arka, I., Bugliaro, L., Reichardt, J., Görsdorf, U., Meyer, C., Strandgren, J., Horvath, A. - High-resolution modeling of high-CAPE summer convection -role of ice microphysics and large-scale forcing, in preparation.

11. Final Report Project bb1041

Project title: Module S2, WP1 & WP4
Project lead: Vera Schemann
Reporting period: 01.01.2019 - 31.10.2019

1. What was this computation time used for?
The computing time was mainly used for high-resolution simulations around the supersite JOYCE. For 2019 the main purpose was, to perform more simulations in order to create the possibility of statistical assessments and comparison with observations. We focused on two main subjects:

- The formation of drizzle and the characterization of boundary layer clouds in the ICON-LEM. This analysis is still focused on the HOPE period due to the available measurements.
- The representation of ice-growing processes during winter frontal systems around JOYCE. In 2015 and again 2019 two intensive observation periods with radar measurements (TRIPEX) took place. These observations are now compared two the ICON-LEM simulations.

The statistical assessment based on several simulations allows us to identify robust signals and potential biases.

In summary, the computing time within this project was used to develop and establish an ICON-LEM testbed setup with a resolution up to 50m and especially the last months (and the remaining months) were used to perform enough simulation for a statistical assessment and comparison to observations.

2. Where there deviations from the schedule? Why and why was this necessary? What was done instead?
The research focus was still mainly on JOYCE, as new opportunities due to the manifold instruments and observational capabilities came up. But we did spend the computing time on high-resolution simulations with the aim to evaluate and improve the model.

3. Publications (also submitted and in review) that use data that was gained during the project

Marke, T., S. Crewell, V. Schemann, J. H. Schween, and M. Tuononen, 2018: Long-Term Observations and High Resolution Modeling of Mid-Latitude Nocturnal Boundary-Layer Processes Connected to Low-Level-Jets, J. Appl. Meteor. Climatol., 57, 1155–1170, https://doi.org/10.1175/JAMC-D-17-0341.1.

Marke, T., U. Löhnert, V. Schemann, and S. Crewell 2019: “Land surface induced water vapor patterns”, *Atmospheric Chemistry and Physics*, https://doi.org/10.5194/acp-2019-322 (submitted)

More publications are in preparation.