BMBF Verbundprojekt

HD(CP)^2

High definition clouds and precipitation
for advancing climate prediction

Report on DKRZ Resources in 2020

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 2020-01-01 to 2020-10-31. The individual project numbers are

- bm0834
- bm0852
- bm0982
- bm0994
- bb1018
- bm1027

The numbers for used computation time and used storage resources are taken as on 30 September 2020 unless stated otherwise.

The reports from the projects bm1027 and bm0994 are the **final reports** and the projects are not asking for computing time or storage resources in 2021.

List of Content

1. Report Project bm834

Project title: HD(CP)2 module M, Cross-cutting Modelling Activities
Project lead: Björn Stevens (MPI-M), Joachim Biercamp (DKRZ)
Reporting period: 01.11.2019 - 31.10.2020

Overview

	Allocated for 2020	Consumed (30.10)	Consumed in total
Computing time (node*h)	6.190	4.718	
Temporary storage /work (GiB)	326.899	93.585	
Storage /arch (GB)	100.000	22.618	3,755.168
Long term storage /doku (GB)	20.480	8.638	115.440

In 2020 the project bm0834 was transformed from the main account where the community experiments were performed, into a so-called data project, that manages, stores and distributes the core products of the individual HD(CP)^2 projects.

Thus from Nov. 2019 to Oct 2020 we reduced the consumption of LUSTRE /work space from 1,227.000 GiB to 93.585 GiB and freed more than 90% of the previously used resources.

In 2020 the project bm0834 used MISTRAL computing time just for postprocessing tasks, thus we only asked for a very small amount of computing time (10.000 node*h), got granted 6190 node*h and consumed 1718 n*hours until end of October 2020.

After the official end of the HD(CP)^2 project end of Sept 2019 some of the S – subprojects received "Kostenneutrale Verlängerung" for three to six months and the Project S6, connected with the DKRZ account bb1018 the HD(CP)^2 project continued with their experiments of NAWDEX. Nevertheless, the production of data slowed down.

The project core data from the formally eleven DKRZ accounts were continuously moved to the data project bm0834. Futhermore, data connected with papers were put to /doku to be stored for 10 years to fulfil the "Gute wissenschaftliche Praxis".

It is planned to continue this storage and basic data management activity at least until end of the last HD(CP)^2 project bm1027 in Feb. 2020.

2. 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 /Verma b309131)

During the last computing period we have performed high resolution ICON-LEM simulations over Germany studying contrail formation within natural cirrus in different synoptic situations and analyzed the impact of preexisting ice crystals within natural cirrus on contrail formation, i.e. the contrail formation threshold, contrail ice nucleation and ice crystal loss in the contrail's vortex phase. As planned we extended our simulations and analysis to another day simulating contrail formation now inside a frontal cirrus. This frontal cirrus is optically much thicker than the in-situ cirrus and therefore has a much larger impact on contrail formation. A paper on this study (Verma and Burkhardt, 2020) is currently being written. The work is also part of a PhD thesis (Verma, 2020).

We estimate the change in the 'emitted' water vapor caused by the sublimation of cirrus ice crystals when aircraft fly through a pre-existing cirrus cloud and cirrus ice crystals are sucked through the aircraft inlet and sublimate in the aircraft's engine. The sublimated cirrus ice crystals must be added to the water vapor emitted by the engine when combusting fuel in order to study contrail formation. The percentage change in total water vapor emission due to the sublimation of cirrus ice crystals on the 24th and 26th April 2013 is fairly low in most situations.

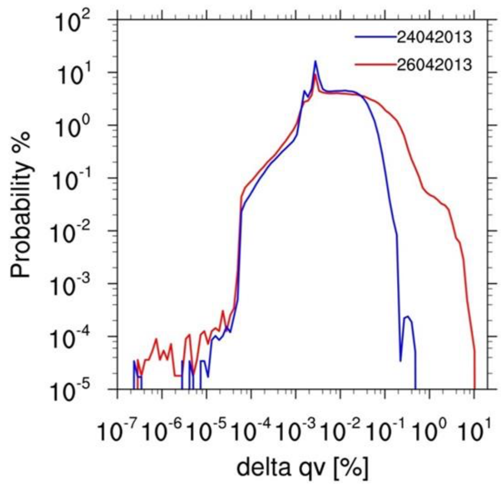

Figure 1: Probability of the percentage change in total water vapor emission (water vapor connected with the combustion of fuel and connected with the sublimation of cirrus ice crystals) due to the sublimation of cirrus ice crystals on the 24th and 26th April 2013.

The increase in the water vapor mixing ratio within the plume causes an increase in the contrail formation threshold temperature. The increase can be significant when traversing frontal cirrus (26th April 2013) and is negligible when flying through a thin in-situ forme cirrus layer (24th April 2013) consistent with the small changes in total water vapor emissions (fig. 1). At lower altitudes where ice water content and number concentration of ice crystals within the natural cirrus are high the change in the formation threshold can be large. Figure 2 shows the change in Schmidt-Appleman threshold temperature (Tsa) on the 26th April 2013 and on the 24th April. On the 26th the change in the threshold temperature can reach values of up to .67K for the lower and warmer atmospheric levels (ambient temperatures between 223K and 227K) and values of up to .33K for the colder ambient temperatures between 215K and 221K.

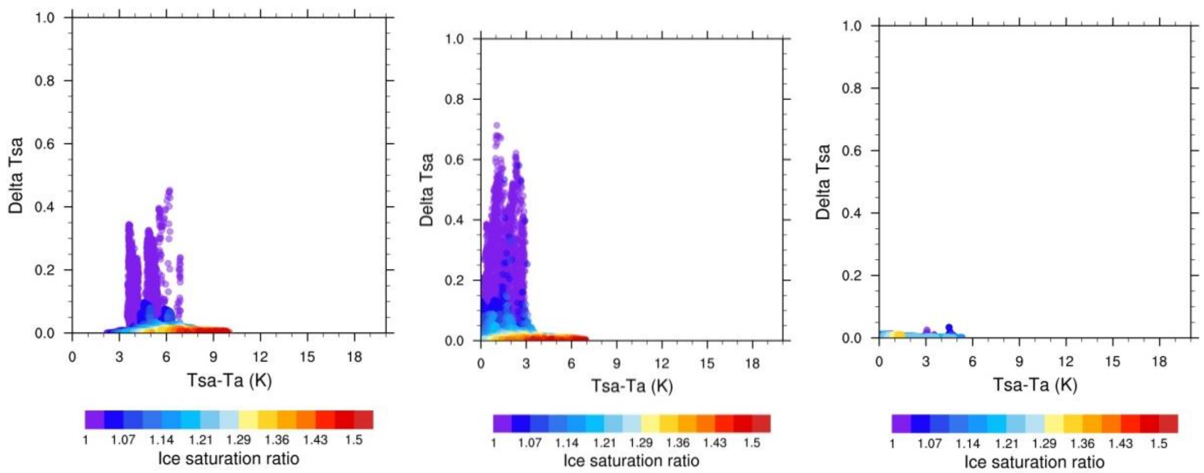

Figure 2: Difference between the Schmidt-Appleman temperature threshold (Tsa) and the ambient temperature and change in Tsa due to sublimation of cirrus ice crystals on the 26th April 2013 5pm at altitudes of 10.3 to 10.8km (left) and at 9.6 to 9.8km (middle) and on 24th April 2013 6am at altitudes of 9.6 to 9.8km(right).

Sublimation of cirrus ice crystals can lead to large changes in contrail ice nucleation (figure 3) and ice crystal survival in the contrail’s vortex phase (not shown). Both processes are parameterized within ICON-LEM. Contrail ice nucleation is dependent on the maximum ice supersaturation that would be reached within the plume when neglecting droplet formation and ice nucleation and, therefore, on the difference of the ambient air temperature and the contrail formation threshold temperature. Even a small change in the formation threshold can have a large impact on the number of nucleated contrail ice crystals particularly when contrail formation happens close to the formation threshold temperature (figure 3). This is caused by the steep increase of contrail ice nucleation with distance from the temperature threshold. Ice nucleation is significantly increased in areas of large ice water content (IWC) which is here connected with large ice crystal number concentrations (qni).

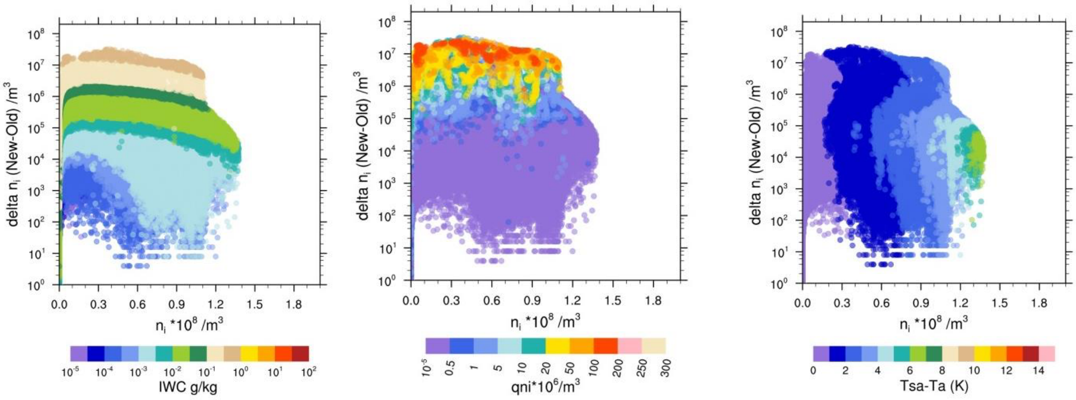

Figure 3: Concentration of newly nucleated contrail ice, n_i, and its change due to the sublimation of cirrus ice crystals within the aircraft engine, delta n_i, at an plume age of approximately 5 minutes for altitudes from 9.6km to 9.8km and their dependency on cirrus cloud properties, IWC (left), qni (middle), difference between temperature formation threshold and ambient temperature (middle) are shown in color. All figures: for the cirrus cloud properties on the 26th April 2013 5pm.

Furthermore, contrail life cycle experiments have been performed analysing the life cycle of cirrus perturbations caused by contrail formation within the natural cirrus. The next step will be to study the impact of contrail formation within cirrus on microphysical and optical properties of cirrus and to obtain a better statistic by performing simulations for different days. We are planning to perform longer simulation for another specific synoptic situation (ML-Cirrus) in order to compare with observation.

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

During the last computing time period we contributed to the HD(CP)2 publication on the performance of the ICON-LEM run over Germany regarding summer time convection (Rybka et al.) and the two publications mentioned in the last computing time report were published. This meant that we concentrated on analyzing high resolution simulations using the pp-Nodes. The planned work regarding the analysis of ICON-LEM simulated convection, the change in the ICON-GCM cloud parameterization and finally the ICON-GCM simulations could not be carried out due to a long sickness, COVID related lack of childcare and later in the year the end of the contract of Dr. Arka. We hope to finish up the work with reduced manpower eventually.

Reference

Verma, P. and U. Burkhardt: Contrail formation within cirrus: high-resolution simulations using ICON- LEM, in preparation.

Verma, P.: Contrail formation within cirrus and their impact on cirrus cloudiness, PhD thesis in preparation.

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, 2020.

Costa-Surós, M. et al - Detection and attribution of aerosol-cloud interactions in large-domain large- eddy simulations with ICON, 2020.

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 review.

3. Report Project bm982

Project title: HD(CP)2-II S4 (Land Surface Heterogeneity)
Project lead: Stefan Poll
Reporting period: 01.01.2020 - 31.10.2020

Overview

Granted computation time for 2020: 70245	used until 22.10.2020: 79167 (113%)
Granted storage on Lustre (/work): 26800	used, 22.10.2020. 25373 GiB (95%)
Granted storage on HPSS (/arch): 20000	used, 22.10.2020: 0 GB
Granted storage on HPSS (/doku): 3000	used, 22.10.2020. 0 GB

Activities Project bm0982

For 2020, an amount of 70245 node hours was granted for DKRZ project bm0982. In the reporting period, the following simulations have been performed on this computing account are used for investigation of the interaction between land-surface heterogeneity and convection and the interplay between convection and cold pools. In total three different subprojects were subject for investigations: Convective precipitation in dependence on model and land-surface resolution, cold pools and self-organization of convection, and grid resolution dependency of land surface heterogeneity effects.

Based on the studies with the use of computing time granted of the project 982, three publications were published, three additional are recently under review and two publication are in active process in 2020.

Convective Precipitation in Dependence on Model and Land-surface Resolution

Clouds are complex bodies because they consist of numerous droplets interacting through a variety of cloud-physical processes. For example, its growth and dissolution due to evaporation are very complex and take place at a very fine scale. Convective precipitation is one of the difficult phenomena to capture in the model simulation.

The focus of this study is to investigate the impact of model grid spacing and land-surface resolution on clouds and precipitation using ICON-LEM simulations and to determine the processes which result into the differences across model grid spacing (Δh). It furthermore explores the capability of ICON - in dependence of grid spacing and land-surface resolution - to simulate those processes, which are responsible for the triggering of convective precipitation.

At first, the geographical areas with a hierarchy of orography and associated deep convection Germany-wide are selected. These three regions are: i) the flat terrain near Berlin, ii) the isolated mountain range in the central part of Germany, called as Harz mountains, and iii) the complex terrain, the Black Forest mountains. Six suitable days with low synoptic forcing, two for each area, are selected. After selecting the areas and suitable cases, the ICON-LEM simulations are designed with six model grid spacings in a nested setup called as control runs: NWP (Δ_x=5000 m, 2500 m), LES (Δ_x=1250 m, 625 m, 312 m and 156 m) with the same model configuration. The control run Δ_x=156 m is named reference run, and all results are compared with respect to this simulation. Moreover, the land-surface sensitivity experiments at a scale of 1250 m and 5000 m have been performed in order to understand the relative impact of land-surface resolution on convective precipitation. That gives in total six sets of control runs and 30 sets of land-surface sensitivity experiments.

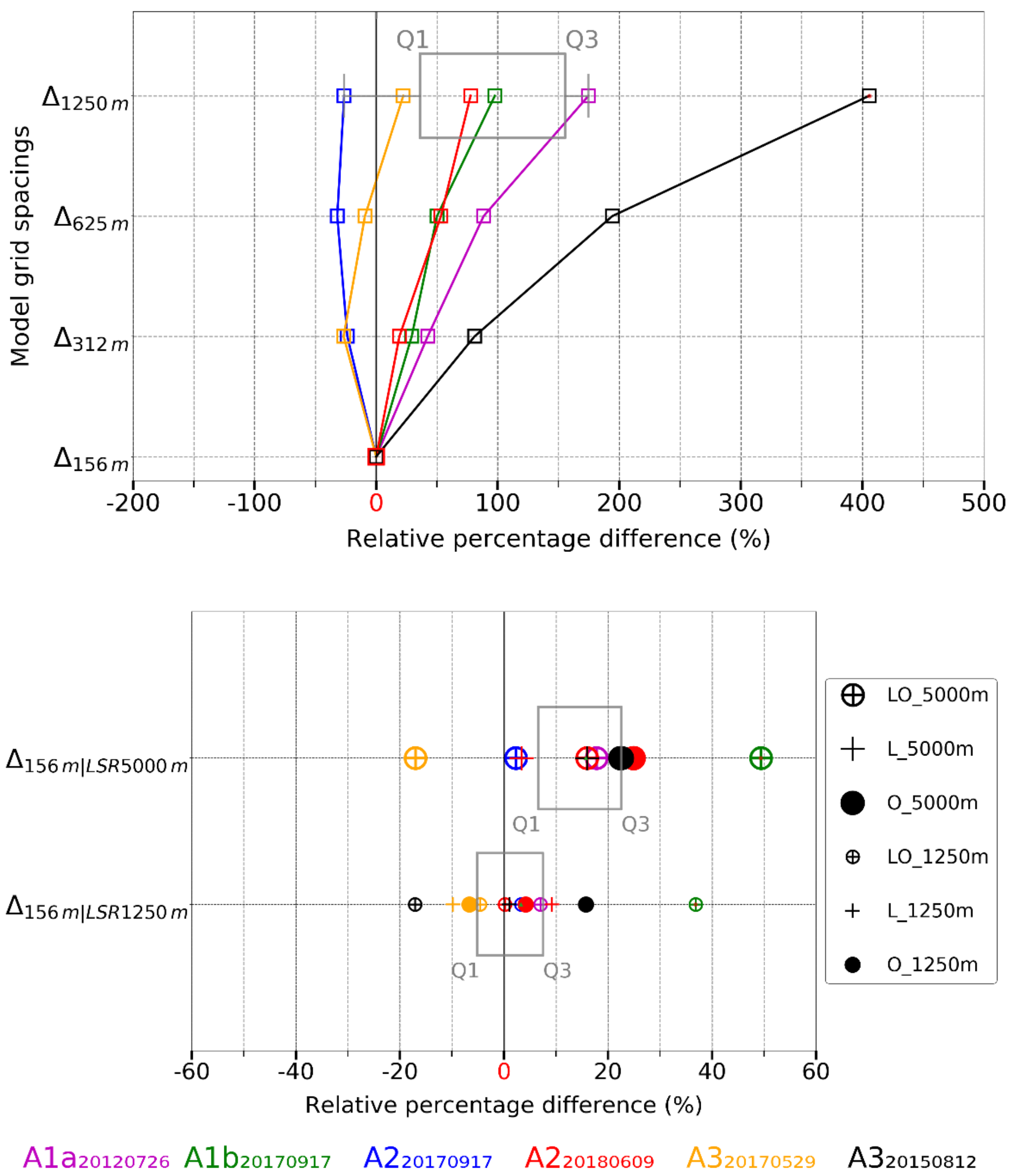

Figure 1: Relative percentage difference of convective precipition of coarser simulation with LES reference (Δ_x=156 m) in dependence of model grid spacing (upper row) and land-surface resolution (lower row). Days and domain of investigation in colour.

The results show that the domain average of accumulated precipitation for most of the cases decreases systematically across the LES grid spacings from Δ_x1250 m to Δ_x156 m (Fig. 1). More specifically, the differences of the areal mean precipitation between the control runs (Δ_x=1250 m, Δ_x=625 m, Δ_x=312 m) and the reference run normalised by the reference run can be quite considerable, i.e. the values are in the range of -26 to 400 % with the 75th percentile of 155 %. It is also found that the precipitating cells in Δ_x1250 m are typically more intense in comparison to the finer LES model grid spacings. Additionally, the onset time of precipitation can differ by 1 to 2 hours (normally precipitation starts earlier in Δ_x1250 m than Δ_x156 m). This is a consistent model behaviour found in the precipitation patterns simulated for all cases. The differences in the real mean precipitation due to the modifications of respective land-surface resolutions are considerably small. The relative differences range from about -17 to 37 % with the 75th percentile of 7 % with the land-surface resolution of 1250 m and increases to a range of -17 to 49 % and the 75th percentile of 22 % with the land-surface resolution of 5000 m. Some part of the above results are published in Stevens et al. 2020.

This offset in model behaviour gives a hint that there is a lack of convergence in simulated mean precipitation at least for model grid spacing $\geq\Delta_x$156 m. Therefore, we performed a test model run at the grid spacing of 75 m for one of the case study at mistral.

These results are under review "Sensitivity of convective precipitation to model grid spacing and land-surface resolution in ICON" in QJRMS (Singh et al., 2020).

Cold Pools and Self-organization of Convection

Within HD(CP)², several idealized studies were carried out to better understand the role of convective cloud interactions on precipitation intensity and convective organization. In Moseley et al. (2016) we found for a transient diurnal cycle setup, that the interaction between convective clouds is important in the lead-up to extreme convective events. The work set the stage for further investigations into the mechanisms involved in cloud interactions and how the lifecycle of isolated and merged convective updrafts can be characterized.

This study was followed up by a detailed investigation of tracked convective rain cells and their statistical properties (Moseley et al., 2019). This paper, which also provided the iterated raincell tracking (IRT) algorithm to the community, found that convective rain cells follow a relatively simple relation between peak track intensity, track duration and average track intensity. This is a useful relation in discussing convective raintracks. Both this result and the tracking method have been used and cited since.

Two studies (Henneberg et al., 2020 and Fournier & Haerter, 2019) made further use of this tracking software and the associated diurnal cycle datasets, in order to develop tracking software for the gust fronts of the resultant cold pools. This cold pool tracking identifies the narrow lines of strong convergence, typically delimiting the cold pool from the environment, and tracks this so-called gust front in time. Such tracking is used in current and future work within my group.

In a recent, simulation-heavy, idealized study we further investigated the effect of the diurnal cycle on convective cloud organization. Starting from homogeneous initial conditions and imposing a surface temperature diurnal cycle (sinusoidally-varying), we were able to show that the atmosphere spontaneously organizes into rainy and rain-free subregions. These subregions roughly resemble a checkerboard pattern, which alternates from day to day (Fig. 2). The individual grid boxes of the checkerboard correspond to the spatial extent of a mesoscale convective system (MCS, scale: approximately 100 km in diameter). It was important to choose relatively high spatial resolution (1 km or higher), relatively large domain size, and relatively long simulation times (~10 days) in order to obtain such clustering. Smaller domain size or shorter durations would have not allowed to obtain a sufficiently clear self-organized pattern, as the lateral boundaries would have forced the pattern - leading to a model artefact. A number of sensitivity studies were carried out, in particular, reducing the amplitude of the diurnal cycle forcing, causing a collapse of the organized pattern. Further, resolution was systematically increased, finding that organization becomes more intense at higher resolution - hinting again at cold pool induced organizational effects. The data are made available to the community.

In a recent study (Nissen & Haerter, *under review*), we investigate the resolution effect as well as the effects of cold pool strength (moderated through changes to rain evaporation) on convective self-aggregation. It is found that a simple model, based on expanding circles and their collisions, can mimic convective self-aggregation - and points to the relevance of cold pool interactions in preventing convective self-aggregation. Again, higher resolution allows cold pools to interact more efficiently and inhibit convective self-organization. Weakening cold pools led to fast segregation into a self-aggregated state. The data will be available to the community.

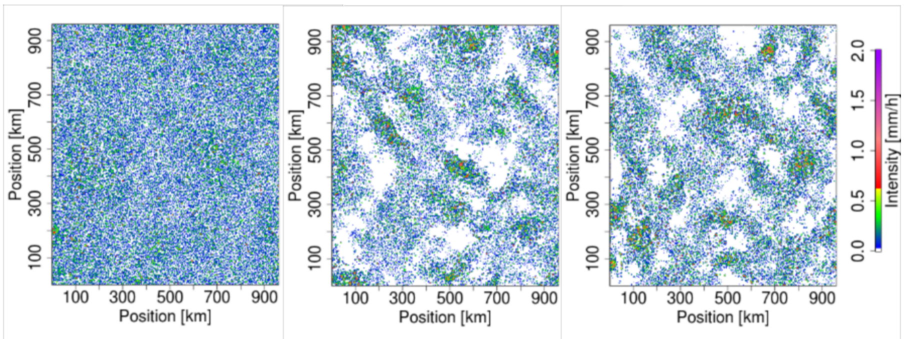

Figure 2: Spontaneous clustering in the diurnal cycle. Self-organization of the diurnally-averaged convective cloud field from a relatively random pattern (day 1, left) to a structure, alternating pattern on days 4 and 5 (central and right panels).

Grid Resolution Dependency of Land Surface Heterogeneity Effects

Land surface heterogeneity exerts a strong control on atmospheric boundary layer (ABL) evolution by spatially varying the distribution and partitioning of surface energy fluxes. In the terra incognita range of model resolution, numerical effects may additionally impact the simulated ABL states, which is the focus of this study.

We analyse these effects for a mesoscale strip-like land surface inhomogeneity in land cover, soil moisture or both combined, embedded in an elsewhere homogeneous landscape. The numerical sensitivity study is conducted with the global weather prediction model ICON

(Icosahedral Nonhydrostatic model) with the ICON-LEM (ICON Large-Eddy-Model) simulation as a benchmark.

The ICON model is used in NWP and LEM mode to simulate the PBL evolution with varying grid resolutions and land surface heterogeneities using an idealized setup for an area of 144 x 80 km with double periodic boundary conditions. The (horizontal) domain is enlarged along the mean wind direction to minimise boundary affects in the central analysis area (containing the 20 km wide strip of inhomogeneity), by keeping it sufficiently distant from the boundaries. One LES resolution (300 m) and five NWP grid resolutions ranging from 300 m to 4800 m with a stepwise coarsening of the grid resolution by a factor of two, two atmospheric conditions, and three land heterogeneity of the strip and its surroundings result in 36 simulations.

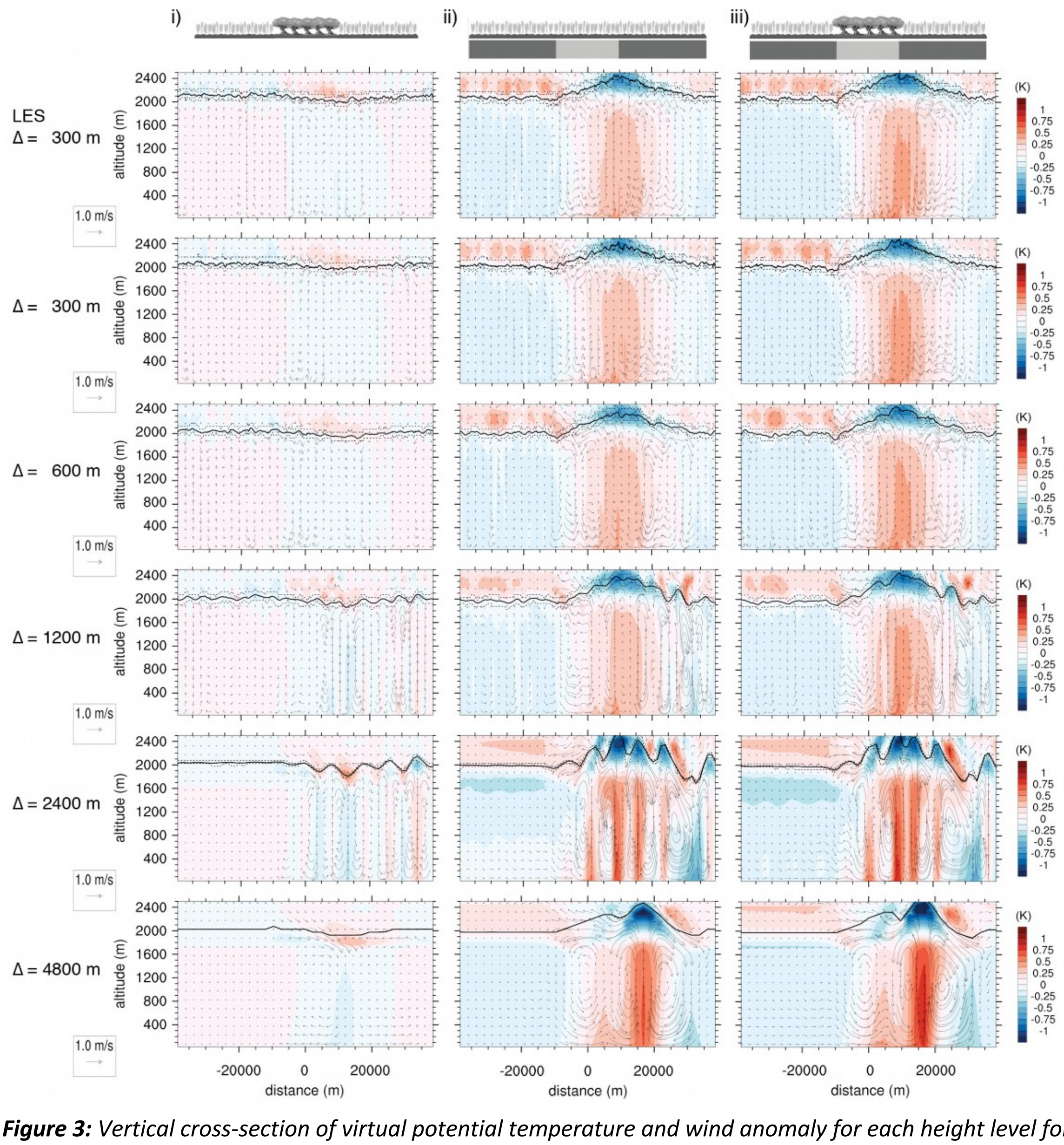

Figure 3: *Vertical cross-section of virtual potential temperature and wind anomaly for each height level for cell condition three hours after initialization averaged in y direction. The sub-figures in the rows show the results for the LES (reference) and the five NWP simulations with resolutions Δ_x= 300 m, Δ_x= 600 m, Δ_x= 1200 m, Δ_x= 2400 m and Δ_x= 4800 m. The columns refer to the results for the three land surface heterogeneities. The black thick solid line indicates the PBL height with the 25% and 75% quantile as dotted lines.*

While simulations with the NWP scheme approach the ICON-LEM simulations when refining the spatial grid towards the ICON-LEM resolution, the model generates artificial circulations leading to boundary-layer height oscillations when the horizontal grid resolution approaches the length scale of the largest eddies in the boundary layer (Fig. 3). In our kilometre-scale simulations the edges of land surface heterogeneity may trigger such artificial circulations. Model-induced circulations are most dominant under calm background wind and weak thermal contrasts. Model-induced circulations are problematic, because they may change the atmospheric state, and depending on the degree of the heterogeneity they may dominate the atmospheric response in terra incognita simulations and exaggerate the effect of land surface heterogeneities. The induced change of the ABL might affect the development of clouds, which are preferably initiated along the updraft regions and might cause convective initialization above the PBL and thus severely affect forecast skill.

We test a ABL parameter tuning using the asymptotic turbulent mixing length scale for its effect on reducing the artificial model circulations. These circulations are effectively attenuated by using a two-dimensional field of asymptotic turbulent mixing length scale corresponding to the land surface heterogeneity, leading to an improvement of boundary layer states.

This study is under review “Grid Resolution Dependency of Land Surface Heterogeneity Effects on Boundary Layer Structure” in QJRMS (Poll et al., 2020).

Justification of shifted computing time:

3061 node*hour expired in March 2020 due to some issues in setting up the model. In the second and third quarter of 2020 no computing time expired.

References

Singh et al., 2020, Resolved and un-resolved: Convective triggering mechanism in ICON, in progress

Poll S., 202x, Land Surface Heterogeneity Effects on Boundary Layer Structure in Climate Simulations, *PhD thesis*, in progress

Poll S., P. Shrestha, C. Simmer, 2020, Grid Resolution Dependency of Land Surface Heterogeneity Effects on Boundary Layer Structure, *QJRMS*, under review

Singh S., L. Gantner, N. Kalthoff, 2020, Sensitivity of convective precipitation to model grid spacing and land-surface resolution in ICON. *QJRMS*, under review

Nissen S. B. and J. O. Haerter, The initial symmetry breaking in convective self-aggregation, *under review*

Singh, 2020, Convective precipitation simulated with ICON over heterogeneous surfaces in dependence on model and land-surface resolution, *PhD thesis*

Stevens, B., Acquistapace, C., Hansen, A., Heinze, R., Klinger, C., Klocke, D., ... & Arka, I. , 2020, The added value of large-eddy and storm-resolving models for simulating clouds and precipitation. *Journal of the Meteorological Society of Japan. Ser. II*. doi.org/10.2151/jmsj.2020-021

Haerter J.O. , B. Meyer, S. B. Nissen, 2020, Diurnal self-aggregation, *npj Climate and Atmospheric Science*, **3**, 30

Henneberg O. , B. Meyer, J. O. Haerter, 2020, Particle-Based Tracking of Cold Pool Gust Fronts, *Journal of Advances in Modeling Earth Systems* **12** (5), e2019MS001910

Moseley C. , O. Henneberg, J. O. Haerter, 2019, A statistical model for isolated convective precipitation events, *Journal of Advances in Modeling Earth Systems* **11** (1), 360-375

Fournier M. B., J. O. Haerter, 2019, Tracking the gust fronts of convective cold pools, *Journal of Geophysical Research: Atmospheres* 124 (21), 11103-11117

Moseley C. , P. Berg, J. O. Haerter, 2016, Intensification of convective extremes driven by cloud–cloud interaction. *Nature Geoscience* **9.10**: 748-752.

4. Final Report Project bm994

Project title: HD(CP)2, S3, TP2
Project lead: Peter Spichtinger
Reporting period: 01.11.2019 - 31.10.2020

Overview

Granted computation time for 2020: 6690Nh	used until 22.10.2020: 4789 Nh
Granted storage on Lustre (/work): 15000 GiB	used, 22.10.2020. 7631 GiB
Granted storage on HPSS (/arch): 5850	used, 22.10.2020: 0 GB
Granted storage on HPSS (/doku): 3000	used, 22.10.2020. 0 GB

What was this computation time used for?

During 2020 we carried out ensemble simulations (approx. 10 members) for three WCB cases in order to determine the impact of environmental conditions as well as the formation of ice clouds via different pathways of formation.

Moreover, we investigated the issue of in situ vs. liquid origin ice clouds, as described in Krämer et al. (2016) for a ensemble of simulations.

Furthermore, to investigate the impact of embedded convection on ice formation pathways in WCBs, we performed simulations using an advanced model setup utilizing a convection resolving grid resolution of 2.5 km in the North Atlantic domain.

5. 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

Overview

Granted computing time in 2020:	178.600 Nh,	used 53.000 Nh (as of Oct 15)
Allocated storage on Lustre (/work):	353.700 GiB,	used 328.400 GiB (as of Oct 15)
Allocated storage on HPSS (/arch):	162.400 GB,	used 86.300 GB (as of Oct 15)
Allocated storage on HPSS (/doku):	4.500 GB,	used 0 GB (as of Oct 15)

ICON NAO-hindcast simulations

Based on our previous observational work we have performed global ICON-NWP simulations (R2B4 resolution, 47 levels) to assess the impact of cloud-radiative effects and total diabatic heating on the North Atlantic Oscillation (NAO) during the winter period DJFM. These simulations were run as short-term reforecasts, each with a length of 15 days and perturbed with NAO-related heating patterns from either cloud-radiative heating or total diabatic heating. The heating patterns were derived from 5-day mean NAO-heating regressions in the control simulation. A total of 600 reforecast simulations were performed. To further test the long term response of the NAO to the heating patterns, climatological 31-year long simulations of the control setup and with the heating patterns were run. These simulations confirmed our observational results and are currently in preparation for publication (Papavasileiou et al., in prep).
Consumption: 3,800 Nh; 26,000 GB work

Regional cloud-locking simulations

We extended the investigation of the impact of regional cloud-radiative changes on the response of the midlatitude circulation to global warming. To this end, we performed global ICON-NWP simulations (R2B4 horizontal resolution, 47 levels) with prescribed sea surface temperatures and the cloud-locking method. In a first step, we investigated the impact of cloud-radiative changes in the midlatitude region of the Northern and Southern Hemisphere, as well as in the polar regions. Together with our earlier simulations this allowed us to show that inter-hemispheric teleconnections are not important. In a second step, we focused on the impact of tropical cloud-radiative changes, which we showed to dominate the cloud-radiative impact (Albern et al. 2020). To this end, we performed simulations to investigate the impact of cloud-radiative changes over the tropical Atlantic, the Indian Ocean, the tropical western Pacific, the tropical eastern Pacific, and combinations of different ocean basins. The latter include the impact of simultaneous cloud-radiative changes over the Indian Ocean, western and eastern tropical Pacific, over the western and eastern tropical Pacific, and over the Indian Ocean and western tropical Pacific. For each region, we performed four simulations with a length of 30 years each. A main result of these simulations is that cloud changes over the Indian Ocean and Pacific contribute substantialla to the robust jet exit strengthening over Europe. These results are currently written up for publication (Albern et al, in prep.).

Consumption: 26,000 Nh; 10,200 GB work; 85,000 GB archive

NAWDEX ICON limited-area simulations in NWP and LEM setups

We have continued our work on ICON limited-area simulations for the NAWDEX field campaign (Sep and Oct 2016). In addition to the extensive set of simulation run in previous years, we in 2020 have conducted addition NWP simulations at 2.5km horizontal resolution with explicit deep convection but parametrized shallow convection. This now extended set of NWP simulations was analysed and compared to MeteoSat data in collobaration with Fabian Senf from Tropos Leipzig, showing that the 2.5km model with only shallow convection shows the best agreement with MeteoSat (Senf, Voigt et al., 2020). We also continued our work on the warm conveyor belt of NAWDEX cyclone Vladiana. This work is close to submission (Choudhary and Voigt, to be submitted). Moreover, we have analysed the whole set of NWP simulations during 2 hackathons, for which we used the jupyterlab of DKRZ/Mistral. A 3rd hackathon is scheduled for November 2020. The ongoing analysis of these simulation continues to require a large allocation on work, as the entire NWP data needs to be available during the hackathons. We also have started the analysis of the LEM simulations, but due to reasons described below this work as been progressed much slower than hoped.

Consumption: 23,000 Nh; 292,000 GB work

Analysis of ECHAM6 and ICON Transpose-AMIP global simulations

We have analysed the Transpose-AMIP simulations with ECHAM6 and ICON-NWP that were previously done by colleagues within HD(CP)2. We made some preliminary comparison for the subset of simulations covering the NAWDEX period with the ERA5 reanalysis product in terms of cyclone tracks and cyclone deepening. This analysis sets the background for our own ICON Transpose-AMIP simulations. The latter were originally anticipated for 2020, but are now re-scheduled for 2021 (see request for 2021). The reasons for rescheduling are described below.

Consumption: 200 Nh

Deviations from original schedule

Our work deviated from the original schedule in three ways. First, the Transpose-AMIP simulations could not be accomplished because of delays in finishing the analysis of the limited area simulations of the warm conveyor belt of NAWDEX cyclone Vladiana and the need for the postdoc to become familiar with the Transpose-AMIP. Second, we were unable to find a MSc student for the planned dry simulations, which were therefore not run. Third, we were unable to run the planned additional LEM simulations. The main reason for this continues to be the Corona pandemic, which has severely limited the work of the PI Aiko Voigt in the first half of the year and has created a substantial back log. The LEM runs are shifted to 2021 and will not be conducted by the PI but a postdoc with ample ICON modeling expertise. The shift in responsibility for the LEM runs is also necessary because the PI Aiko Voigt will start a professorship at University of Vienna in 2021. The BMBF project that funds the work of bb1018, however, will continue until 2022 so that computing resources for bb1018 will continue to be required until 2022.

Publications

Albern, N., A. Voigt, D. W. J. Thompson, and J. G. Pinto (2020): The Role of Tropical, Midlatitude and Polar Cloud-Radiative Changes for the Midlatitude Circulation Response to Global Warming. *J. Climate*, 33 (18), 7927-7943.

Albern, N., A. Voigt, J. G. Pinto: Tropical Cloud-Radiative Changes Contribute to Wintertime North Atlantic Jet Exit Strengthening under global warming*, in preparation.*

Choudhary, A., and Voigt, A., ICON simulations of cloud-diabatic processes in a warm conveyor belt of an extratropical cyclone: A case study, *to be submitted to QJRMS in the coming weeks*.

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6. Final Report Project bm1027

Project title: HD(CP)2 S1 TP4: Cloud adjust
Project lead: Corinna Hoose
Reporting period: 01.01.2020 - 31.10.2020

Overview

Consumed computation time:	500 Nh,	expired 76 Nh
Allocated storage on Lustre (/work):	1000 GiB,	used: 967 GiB
Allocated storage on HPSS (/arch): -		
Allocated storage on HPSS (/doku): **-**		

What was this computation time used for?

We have continued to use 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. Furthermore, the DYAMOND simulations were analysis with respect to cloud properties and moist static energy budget.

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

The project HD(CP)2_S1_TP4 ended in March 2020. As there were difficulties with the recalculation of certain ice formation processes, in particular homogeneous freezing, the technical development took longer than planned and required intensive testing. Therefore the submission of the PhD thesis of Jonas Hesemann is delayed and now planned for early 2021.

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

Publications are still in draft stage.