HD(CP)² - A project on high-resolution modeling

www.hdcp2.eu

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The lack of understanding of cloud and precipitation processes is arguably the foremost problem of climate simulation and climate prediction. The project HD(CP)² (High definition clouds and precipitation for advancing climate prediction) is an inivitative for addressing this problem. It tries to reduce the uncertainty of climate change projections, both on global and regional scales. It combines the work of scientists both from the modeling and observation community towards this goal. HD(CP)² is funded by the German Federal Ministry of Education and Research through the FONA (Forschung für nachhaltige Entwicklungen) initiative. The project is currently running in its second funding phase until March of 2019.

Project Structure

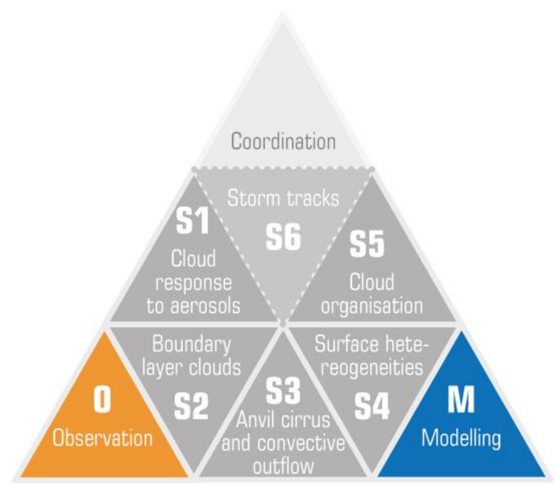

Fig. 1: Cornerstones of the project are the modeling and observational activities that serve the different science teams (S1-S6).

Participating Institutes

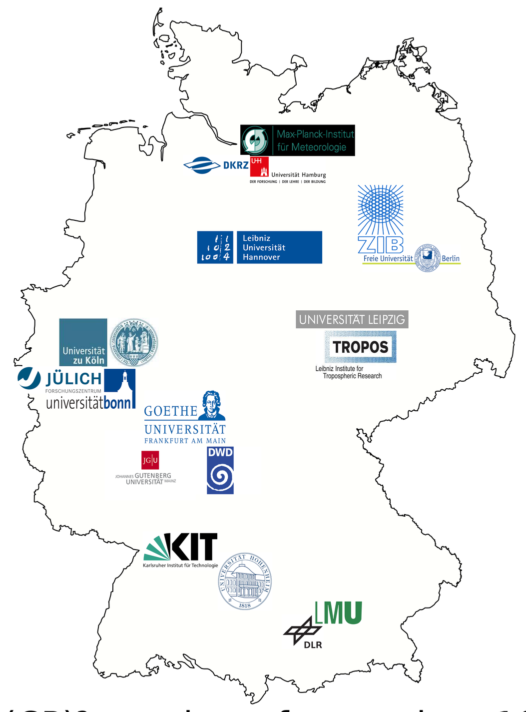

Fig. 2: HD(CP)² consists of more than 100 members from 18 institutions all over Germany.

Simulation Domains

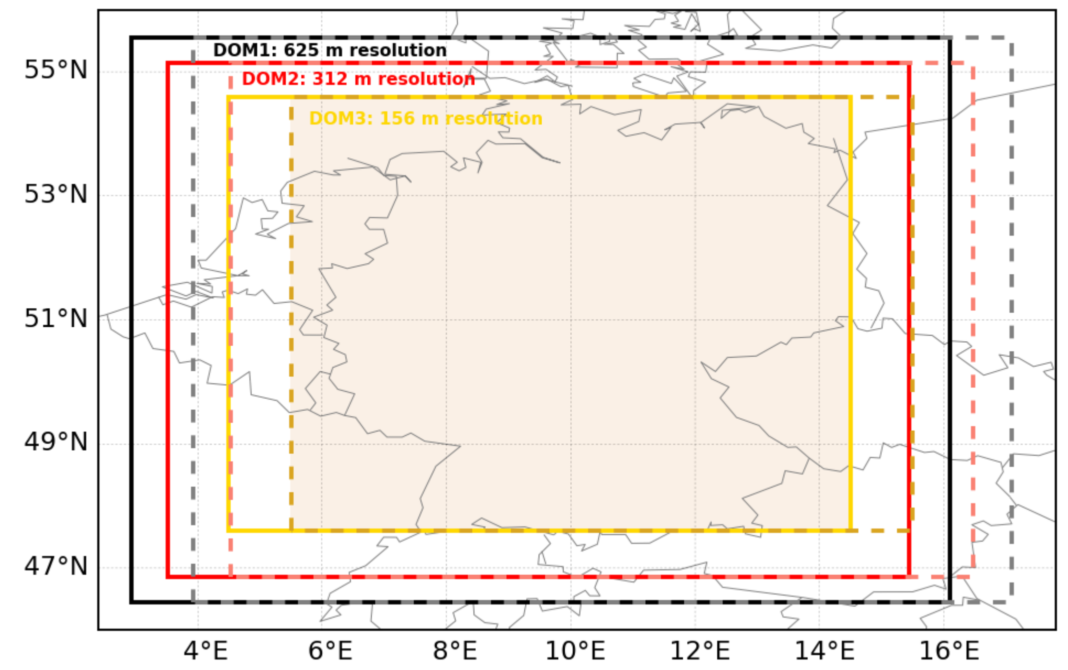

Fig. 3 (R. Heinze): The simulations cover the region of Germany and are performed on three domains with horizontal resolution ranging from 625m to 156m and 150 vertical levels up to 21km. This leads to ~ 4x10⁹ cells.

The project is built on six scientific questions that are investigated by individual science teams:

S1: How do clouds respond to pertubations in their aerosol environment?

S2: What are controlling factors for boundary layer clouds?

S3: What are controlling factors for anvil cloud development?

S4: To what extent does land-surface heterogeneity control clouds and precipitation?

S5: To what extent is convective organization important for climate?

S6: How do clouds and convection influence the development of storm tracks?

Land surface heterogeneity (LSH)

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LSH is expected to influence the boundary layer due to flux partitioning, but its effects cannot be incorporated explicitly in regional and climate models, because of their large spatial grid scale. While tile or mosaic approaches capture the aggregation effects related to surface heterogeneity, they neglect any dynamical effects, such as circulation in the boundary layer and transport of latent heat away from the surface.

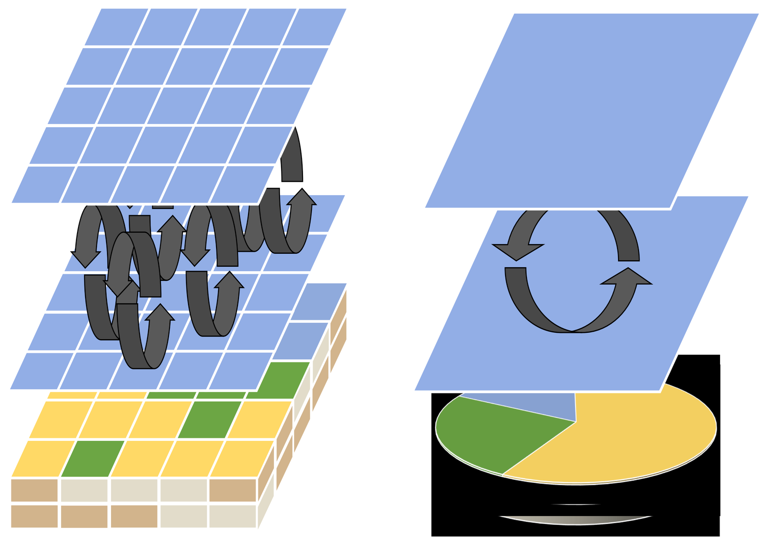

Fig. 4 (S. Poll): Sketch of a high-resolution simulation with resolved circulation (left panel) and a coarse-resolution simulation using the tile approach for the LSH with parameterized circulation (right panel).

It is investigated how large the dynamical effects of parametrized LSH are. ICON is run in different modes (LES, NWP) with/without tile approach and with different horizontal resolution (5km to 156m). It is hypothesized that coarse-resolution simulations need more energy for a circulation to start, leading to a delayed circulation initialization in parametrized scenarious.

Convective organization

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Characterization of convective organization with the help of wavelet spectra and a **w**avelet based **o**rganization **i**ndex (WOI). The WOI describe scales of convection (WOI1), total energy (WOI2), and degree of anisotropy (WOI3).

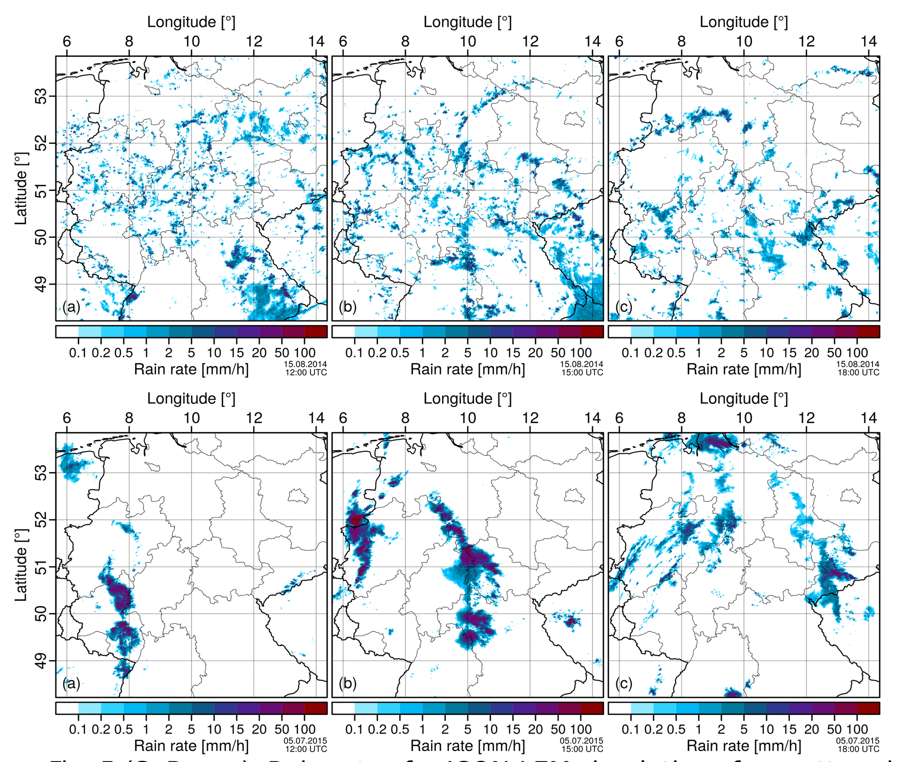


Fig. 5 (S. Brune): Rain rates for ICON-LEM simulations for scattered, isotropic convection on August 15th 2014 (top) and strongly linear, anisotropic convection on July 5th 2015 (bottom). The scales of the convective systems range from ~3km (top) to ~30km (bottom).

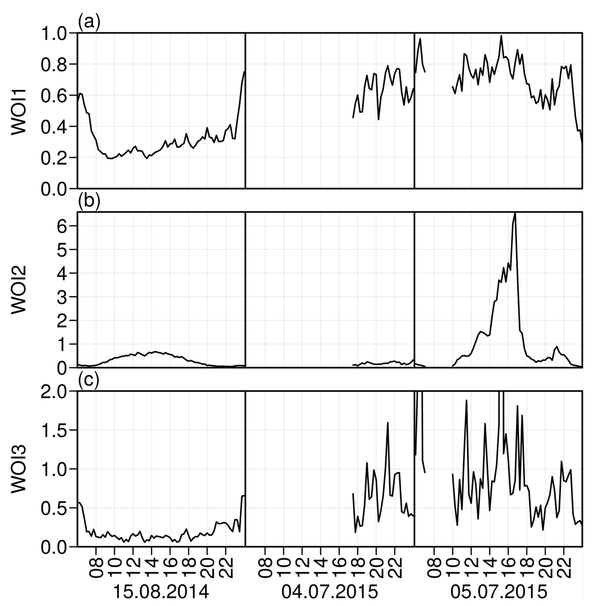


Fig. 6. (S. Brune): Time series of the WOI for both simulations.

Scattered convection is active on smaller scales, its relation between large scale and total energy being small (WOI1 0.5). Strong organized convection is present at larger scales (WOI1 0.5).

Most precipitation (largest WOI2) arises on July 5th 2015, when two convective lines affect Germany.

WOI3 distinguishes clearly between scattered convection (WOI3 around 0) and organized convection (WOI3 0), because especially linearly organized convection (July 5th 2015) leads to a large anisotropy.

Wavelet spectra are able to capture convective organization and are better than other indices (e.g., SCAI[3]). WOI1 gives important information about the size of the objects and WOI3 about the object's direction.

Modeling

Core element of HD(CP)² are its hindcast weather simulations that are done with the ICON-LEM, a large eddy resolving version of the ICOsahedral Nonhydrostatic (ICON) model[1]. The simulations are done at the Deutsche Klimarechenzentrum (DKRZ) and cover very different synoptic situations that are utilized in the various science teams. An overview can be gained through quicklooks that are freely available. Currently, also simulations over the Tropical Atlantic (TA) are set up.

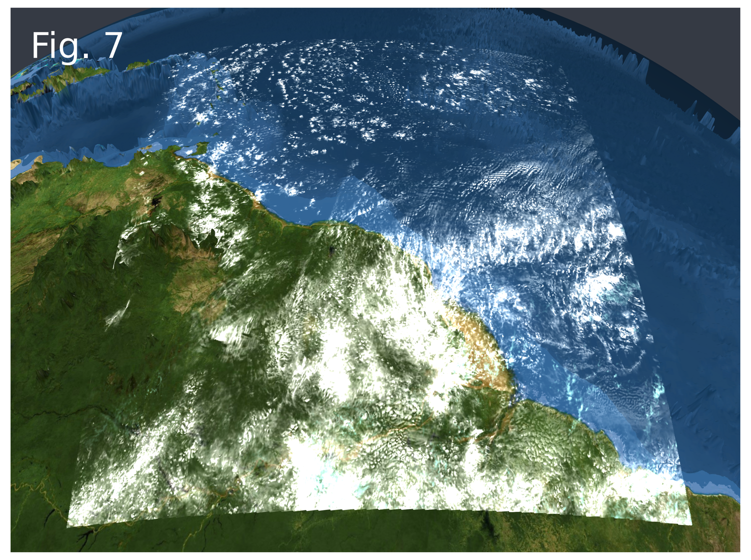
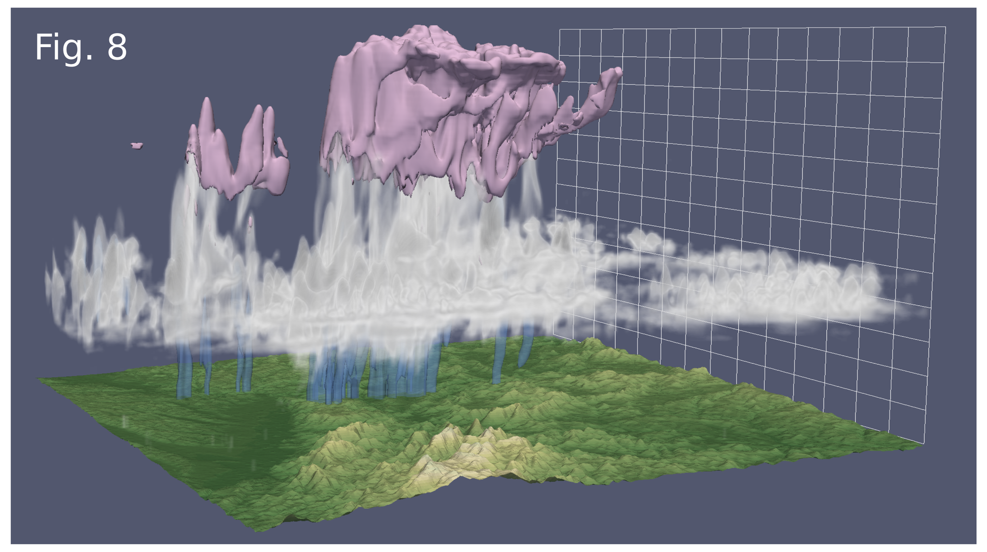


Fig. 7 (M. Brück): First model output for the TA setup (625m resolution).

Fig. 8 (N. Röber): Snapshot from the high-resolution cloud resolving simulations over Germany. Clouds are shown in white, precipitation in blue and cloud ice in pink.

Quicklooks for the various simulations and videos.



Observation

The cross-cutting observational activities constitute the second cornerstone of the HD(CP)² project. This module performed a project-own observation campaign[2] HOPE (HD(CP)² Observational Prototype Experiment) that collected data with high temporal and spatial resolution to provide data for verification and further development of the ICON-LEM. HOPE data is available via the project-own data base SAMD. SAMD established its own data and meta data product standard (using NetCDF naming conventions) and thus allows access to various data sets in a uniform manner. The data base is established as a structure of distributed data servers with a common web portal which is located at the Integrated Climate Data Center (ICDC) in Hamburg. The web portal provides also the meta data information for each data set and the link to the corresponding data server. SAMD can be reached via the HD(CP)² website.

SAMD Standardized Atmospheric Measurement Data

References

[1] Dipankar, A., B. Stevens, R. Heinze, C. Moseley, G. Zängl, M. Giorgetta, and S. Brdar (2015): Large eddy simulation using the general circulation model ICON, J. Adv. Model. Earth Syst., 07

[2] Macke, A. et al. (2017): The HD(CP)² Observational Prototype Experiment HOPE – An Overview, Atmos. Chem. Phys. Discuss., doi:10.5194/acp-2016-990

[3] Tobin, I., S. Bony, and R. Roca (2012): Observational Evidence for Relationships between the Degree of Aggregation of Deep Convection, Water Vapor, Surface Fluxes, and Radiation. J. Climate, 25, 6885–6904, https://doi.org/10.1175/JCLI-D-11-00258.

Max-Planck-Institut für Meteorologie

FONA Forschung für nachhaltige Entwicklungen BMBF

Bundesministerium für Bildung und Forschung

DKRZ

HD(CP)² High definition clouds and precipitation for advancing climate prediction

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