HD(CP)^2: High Definition Clouds and Precipitation for Climate Prediction

The lack of understanding of cloud and precipitation processes is arguably the foremost problem of climate simulations. The BMBF initiative "High Definition Clouds and Precipitation for Climate Prediction" or "HD(CP)^2" for short will focus German community efforts on the understanding of clouds and precipitation processes. By addressing this topic, a significant reduction in the uncertainty of climate change projections, both on global and regional scales, is expected. The project consist of three elements: (i) model development and simulation, (ii) observation, and (iii) synthesis to advance cloud-precipitation prediction. The first phase will be three years to create a high resolution prototype model for a series of summer hindcasts over Germany, to collect data to allow for model evaluation, and to start the synthesis of the produced data. In a potential second phase, the model domain could be extended and complemented by other regions in the world that will allow for a deeper analysis of cloud and precipitation related projects.

Background of the project

Clouds and precipitation are an essential element of the climate system, but they are difficult to account for in theories and models [1]. Clouds significantly influence the atmospheric radiative forcing and modulate many feedback processes of the Earth system. Interactions with the terrestrial biosphere, sea-ice interactions, and biogeochemical interactions are critically dependent on the cloud-precipitation representation [2], [3]. Atmospheric clouds and precipitation are small- and meso-scale phenomena, which cannot be modeled explicitly on the global scale with current computer architectures and hence are parametrized in global climate models. Global climate simulations today show significant biases in precipitation patterns which are related to insufficient parametrization of these processes.

Aim of the project

HD(CP)^2 is a coordinated initiative to improve our understanding of cloud and precipitation events, to increase the quality and number of available observations, and to evaluate and improve our modeling abilities. One group of project partners will develop a highly scalable regional weather model which will be used to provide a series of ultra-high resolution summer-season hindcasts over Germany. This model will start on top of the ongoing efforts of MPI-M and DWD to develop the next generation climate model ICON. The HD(CP)^2 target region for this regional model is illustrated in Figure 1. This figure also shows the density and diversity of the observational network. A second major aim of the project is to improve, homogenise, and understand the multitude of available observations of cloud and precipitation processes in the target region. The network provides ground based measurements that can be combined with satellite remote sensing measurements to evaluate the simulations and to obtain statistics of cloud-precipitation processes. Combining simulation results and observational data from networks and supersites all over Germany will help to improve cloud and precipitation parametrization, allowing for improved climate prediction. The HD(CP)^2 simulations will also help to understand current limits on cloud-precipitation modeling and parametrization skills. The scale of the simulations allows the explicit representation and analysis of entirely new phenomena. For example, in summer months the shallow cumulus cloud regime, which has been shown to be particularly relevant for climate sensitivity, can be investigated. Surface-forced precipitation regimes, whose poor representation underlies much of the uncertainty in current representations of the hydrological cycle, can also be studied.

Challenges

The scales of clouds range from several micrometers, which is the size of a single cloud particle, to hundreds of kilometers, which is the dimension of a frontal system. It is impossible to numerically represent cloud-precipitation processes on scales that span so many orders of magnitude. Some authors have come to speak of the grid spacing range between 1 and 5 km as the grey zone, or Terra Incognita (Figure 2). In this zone many of the key interactions are only partially resolved. Aiming on a horizontal grid spacing of approximately 100 meters, the new HD(CP)^2 model will help to explore the grey scales of cloud and precipitation modeling. By developing the capacity to evaluate simulations of clouds and precipitation on such scales, new frontiers will be opened. Better understanding of clouds and precipitation will provide a basis for improved climate predictions. The HD(CP)^2 project will bring theoretical and observational work together, to a new level of understanding of the role of precipitation and clouds in the climate process. HD(CP)^2 will bring German research efforts to the forefront of high resolution climate modeling and climate data observation.

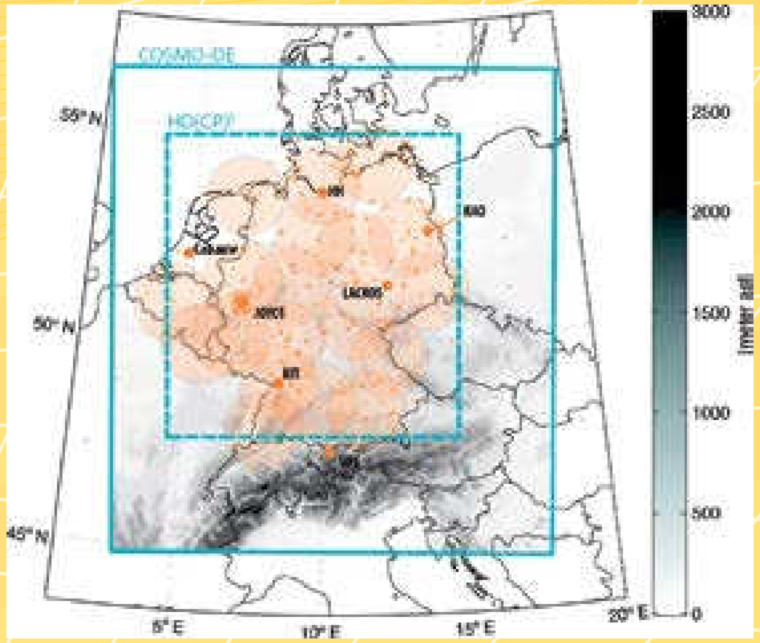

Figure 1: Map showing a possible HD(CP)^2 simulation domain, and the density of observational networks. The model domains are outlined in blue, the orange elements show different measurement instruments of the observational network.

Project Partners

- Computer Science, University of Cologne (CS)
- Deutscher Wetterdienst (DWD)
- Engineering Mathematics and Computing Lab, Karlsruhe Institute of Technology (KIT)
- German Climate Computing Centre (DKRZ)
- Institute of Atmospheric Physics, DLR (DLR-IPA)
- Institute for Energy and Climate, Research Centre Jülich (FZJ-IEK)
- Institute for Geophysics and Meteorology, University of Cologne (IGM)

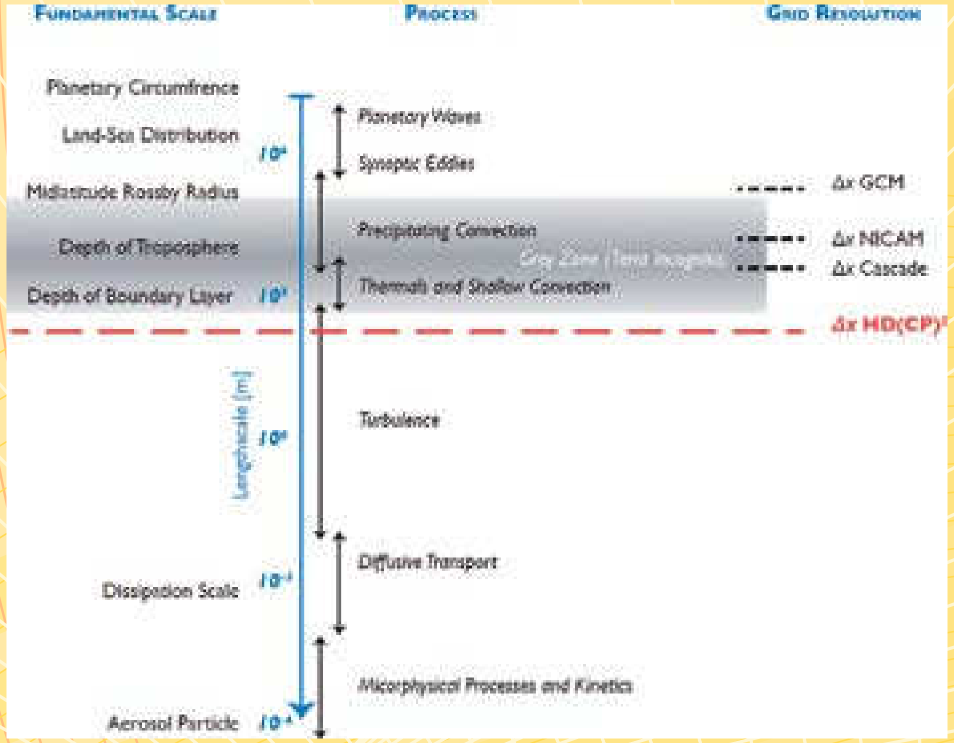

Figure 2: Diagram showing fundamental scales and processes in the atmosphere and the grid spacing employment in state of the art modeling versus grid spacing proposed for this project.

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- Institute for Meteorology and Climatology, University of Hannover (IMuK)
- Institute for Mathematics, University of Mainz (JGU Mainz)
- Institute of Physics and Meteorology, University of Hohenheim (IPM)
- Institute for Space Sciences, Free University of Berlin (FUB)
- Jülich Supercomputing Centre, Research Centre Jülich (FZJ-JSC)
- Leibniz Institute for Tropospheric Research, Leipzig (IfT)
- Ludwig-Maximilians University Munich (LMU)
- Max Planck Institute for Meteorology (MPI-Met)
- Meteorological Institute, University of Bonn (MIUB)
- Meteorological Institute, University of Hamburg (UHH)
- Richard Aßmann Observatory (DWD)
- Zuse Institute Berlin (ZIB)

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[3] **Kay, J. E., L'Ecuyer, T., Gettelman, A., Stephens, G., O'Dell, C.**
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How the ScalaLife project integrates software developers, computing centres and life science researchers

Scalable Software Services for Life Science

The ScalaLife project (Scalable Software Services for Life Science) started in September 2010 and develops new hierarchical parallelization approaches explicitly based on ensemble and high-throughput computing for new multi-core and streaming/GPU architectures, establishes open software standards for data storage and exchange. The project implements, documents, and maintains such techniques in pilot European open-source codes such as the widely used GROMACS & DALTON, as well as a new application for ensemble simulation (DISCRETE).

ScalaLife created a Competence Centre for scalable life science software to strengthen Europe as a major software provider and to enable the community to exploit e-Infrastructures to their full extent. This Competence Network provides training and support infrastructure, and establishes a long-term framework for maintenance and optimization of life science codes.

ScalaLife for software developers

The project offers software developers efficient and scalable methodologies for compute intensive codes. Experts within the ScalaLife project can perform code analysis and profiling for codes that have been approved by the Competence Centre. Furthermore, the utilization of accelerators and alternative platforms (GPGPUs, FPGAs) is being investigated and ScalaLife can help with porting.

Among the experts in the centre are

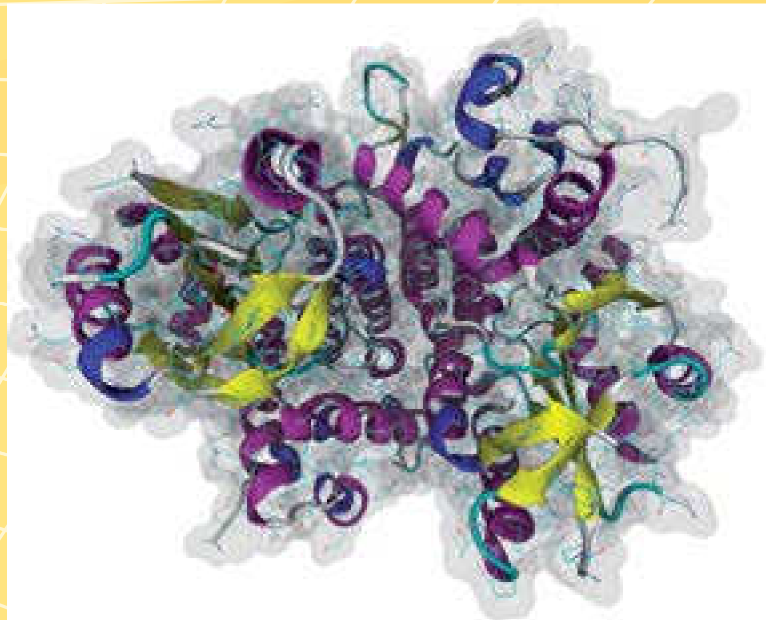

Figure 1: DISCRETE test case: Study of allosteric effects in the dynamics of proteins forming complexes.
The aim is to study the dynamics of several proteins of biological interest that form complexes with small proteins, specifically how the dynamics of a certain protein are changed when it forms a complex with another protein. This change in the dynamics can result in an allosteric effect, i.e. it can lead to a change in the activity of the protein. In some cases this mechanism can work like a switch between the inactive/active state of a protein. Using DISCRETE allows to run long molecular dynamics trajectories, taking advantage of its speed compared with standard MD codes. Contact: Ramon Goni (BSC).