Project: 1154
Project title: Monsoon
Project leader: Dr. Ulrike Burkhardt
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1. Analysis and evaluation of ice clouds in high-resolution simulations (Karol Corko b309188, Ulrike Burkhardt b309022)

Within the BMBF Monsoon project we have continued to analyze high-resolution global simulations performed within the DYAMOND project and compared them with active and passive remote sensing data and ERA5 reanalysis. High-resolution DYAMOND simulations resolve much of the cloud relevant dynamics and cause a large improvement in cloud structure and diurnal cycle of precipitation. Nevertheless, their cloud properties still vary significantly. Our focus is on evaluating the impact of tropical convection on UT ice clouds as tropical cloudiness should particularly benefit from increased resolution because deep convection is mostly resolved. We analyze the horizontal distribution of the total ice water path (IWP), partitioning of total IWP and precipitation, cloud phase and cloud vertical structure as they are crucial to the Earth's radiation budget.

The DYAMOND models generally underestimate the tropical total IWP compared to active and passive remote sensing data. In order to understand better those differences, we analysed the connection between the simulated vertical velocity and IWP. While the PDF of tropical vertical velocity simulated by the different models is quite similar, the total IWP connected with those vertical velocities varies strongly.

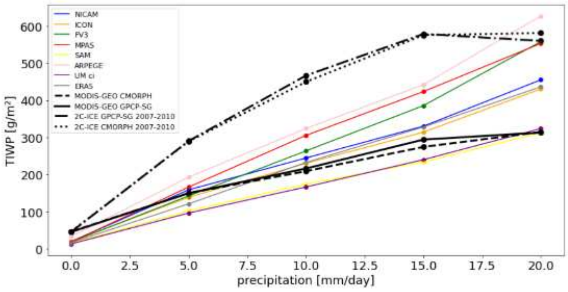

Figure 1: Partitioning of precipitation and total ice water path (water path of cloud ice + graupel + snow)

In order to compare the dependency of IWP on the strength of convection with observational data we chose precipitation as an indicator of the strength of convection. Figure 1 shows the partitioning of convective water in total IWP and precipitation in the simulations of the DYAMOND models and in observations. With increasing precipitation, we expect an increasing total IWP, which models seem to simulate well. Active remote sensing data suggests that total IWP is generally underestimated by the models. The conversion of cloud water into precipitating hydrometeors may be too fast. In areas with no or little precipitation, total IWP is underestimated even relative to passive remote sensing data.

The vertical distribution of the condensate also varies among the models, with NICAM ice water content (IWC) reaching higher atmospheric levels than in other models. Figure 2 shows that CTH and IWC are underestimated by most models when compared to DARDAR and METEOSAT data. We will write a publication summarizing this work in the next months.

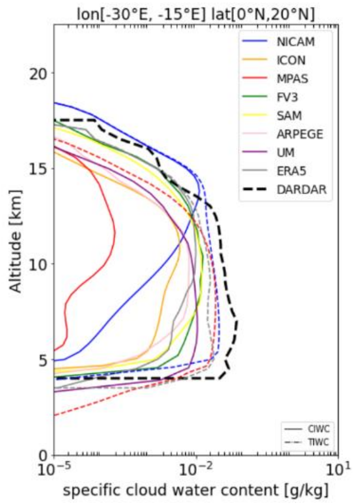

Figure 2: Ice water content of different DYAMOND simulations and DARDAR over the Atlantic Ocean

Unfortunately, we have not yet managed to do the ICON simulations that we had planned for this year and, therefore, used considerably less computing time. In those simulations we aim to determine the sensitivity of the ICON ice clouds on microphysical parameters in order to improve the tropical IWP. We have done first trial simulations with the ICON bubble model and are planning to continue with those simulations in the next months. Afterwards we are planning to run 3D ICON simulations with improved microphysical parameter settings.

2. Test Runs and Debugging (Luis Kornblueh m214089, Reiner Schnur m212005 und Chao Li m221071)

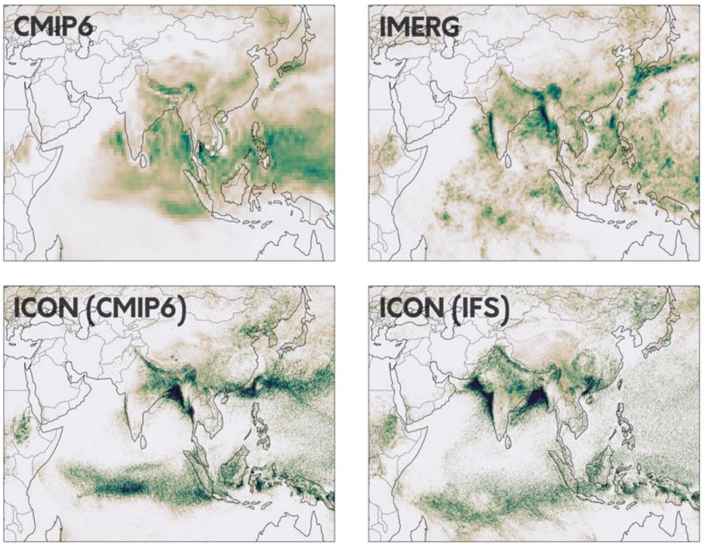

Figure 3 Comparison of the monthly mean precipitation (July) in a general circulation model (CMIP6), satellite observations (IMERG), and two ICON simulations with different boundary conditions.

During the last year we were able to perform an ensemble of global storm-resolving simulations. The synergy of 20 ensemble members and their simulation period of 6 months each provide an exceptional set of data to investigate the statistics of extreme events in different background climates.

Preliminary results highlight the potential of these storm-resolving models for the analysis of precipitation patterns. Figure 3 compares two of our ICON simulations to a general circulation model from CMIP6 and to satellite observations (IMERG). Both ICON simulations show an enhanced representation of precipitation patterns, e.g., at the Tibetian plateau or at the coast of China.

A surprising result is the extent to which the strength of the Indian monsoon depends on the prescribed SST patterns; in our ensemble it is only represented when using an SST analysis product (IFS). One working hypothesis is that changes in the SST gradient impact the circulation pattern around the Indian subcontinent which can distorts the moisture transport needed to sustain the Monsoon precipitation. We plan to further constrain the processes driving these changes in the coming months.

For this year, we were granted a compute time budget of about 250k node hours. This quota was significantly higher compared to the previous year, as we wanted to run some ICON simulations on Levante. During this year, it turned out that we could use significantly more resources on the JUWELS booster cluster at the Jülich Supercomputing Centre (JSC) than originally planned. For reasons of simpler workflows, we therefore decided to run all planned simulations at the JSC. As a result, we only used a small share of our allocated computing time. However, the computational time consumed has increased in recent months as post-processing of the data has begun. We expect this usage to continue or even slightly increase until the end of the year as more project partners will begin analyzing the processed data.

The granted Levante storage was about 800 TB. Throughout the project the used disk space continuously increased due to ongoing data transfer from the JSC. The storage peaked around 600 TB in September. Currently, we convert the model output into different data formats for easier analysis. Therefore, the used storage space varies, but will likely not increase much. The start of more heavy data analysis will likely create the need for intermediate data to be stored. However, we are optimistic that the remaining storage space is enough to facilitate the research.

As of the preparation of this report, we are not using any of our allocated space on the tape archive. However, this will change drastically to the end of the year. Currently, we need all our model output on disk for easier postprocessing and analysis. However, we will start to transfer the raw results to the long-term archive within the next months.