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

Within the BMBF Monsoon project we have continued to analyze high-resolution global simulations performed in the DYAMOND and MONSOON projects and compared them with ERA5 reanalysis data as well as two versions of the NWP ICON model. We performed the comparison on two different time scales – monthly and daily means (climate and anvil time scales). Moreover, we evaluated the models with active (2C-ICE and DARDAR) and passive remote sensing data. Relative to the DARDAR and 2C-ICE data, models significantly underestimate the convective ice water path. While the ice water path is satisfactorily simulated by many high-resolution models for strong convection, the large underestimation of the ice water path is evident for weak convective events or aged systems (indicated by medium strong precipitation) relative to active and even relative to passive remote sensing data (Figure 1). Furthermore, the joint distributions (Figure1 bottom) show that ICON underestimates the variability of IWP for low precipitation amounts indicating a too strong dependency of precipitation on ice water path. The underestimation of the ice water path appears to be caused by a too fast conversion of ice water into falling hydrometeors. A comparison with ICON-NWP simulations shows that both the underestimation of the tropical ice water path as well as the underestimation of ice water path in weakly convective areas is more pronounced than in the higher resolution simulations. This underestimation can be shown to be mostly caused by the model's cloud scheme and to a lesser degree by the convective scale dynamics. The comparison with the simulations of the MONSOON project showed that the mean tropical ice water path is improved while the underestimation of ice water path for aged convection is not improved. We are currently working on compiling our results in the form of a publication (Ćorko et al., in prep).

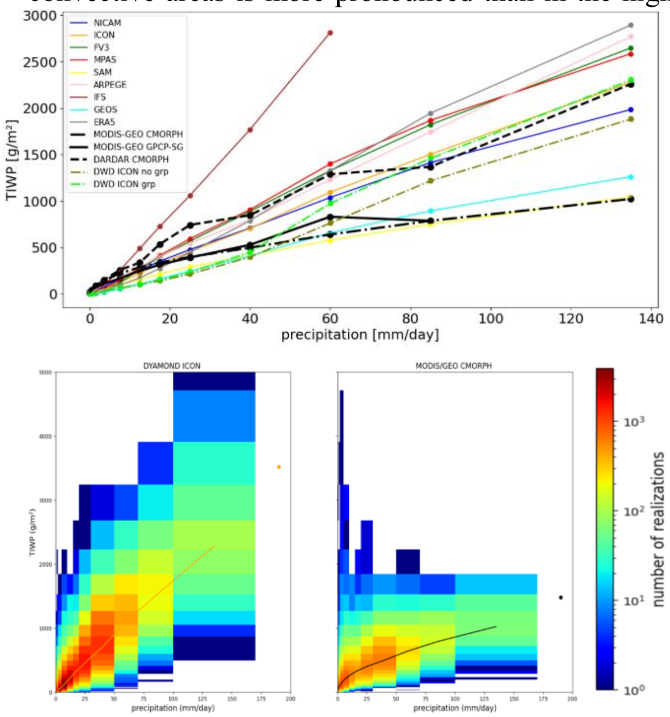

Figure 1 Partitioning of water transported into the upper troposphere into precipitation and total ice water path (water path of cloud ice + graupel + snow) on anvil time scale (top) and its variability for DYAMOND ICON (bottom left) and passive remote observations (bottom right)

Analyzing all six simulated months of the MONSOON project, we find that our analysis results do not vary significantly from one month to the next. Simulations with a higher cloud ice sedimentation rate resulted in a slight increase in the ice water path (particularly in strong convective areas) and in a decrease of the cloud top, which is already underestimated compared to active remote sensing data. It appears that the new ICON setup and the change in the sedimentation rate both result in more frequent strong convective events, whereas observational data suggest that ice-water path is underestimated for weak or aged convective systems.

2. Intensification of tropical precipitation extremes from more organized convection (Luis Kornblueh m214089 und Lukas Kluft m300575)

Bao et al. utilized global storm-resolving simulations from the Monsoon project and high-resolution observations to explore the behavior of tropical precipitation extremes in response to surface warming. The study revealed that the meso-scale organization of convection, a factor unaccounted for in traditional climate models, significantly influences daily tropical precipitation extremes. Both simulations and observations showed that as the climate warms, daily precipitation extremes become more organized (Figure 2), resulting in larger but less frequent storms. Simulating a warmer climate consistently led to a substantial increase in monthly-mean daily precipitation extremes, surpassing expectations based on Clausius-Clapeyron (CC) scaling. The research emphasizes the importance of convective organization, predicted to intensify with warming. These findings underscore the necessity for advanced computing resources to further investigate this non-linear behavior of extreme precipitation, with implications for understanding and preparing for future climate extremes.

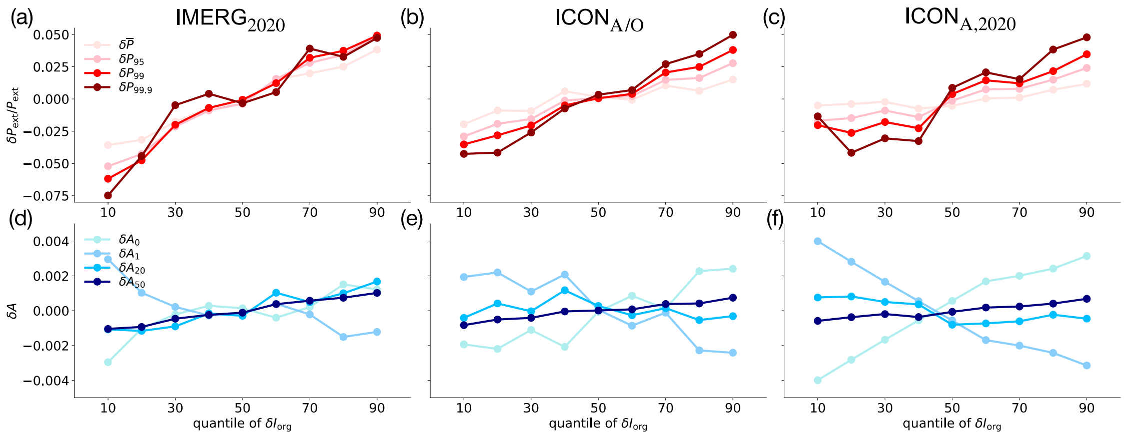

Figure 2 Precipitation amounts and precipitation area sorted by organization.

Computing time

During the previous project phase, we were allocated approximately 15,000 node hours for computing. This allocation primarily supported post-processing activities related to high-resolution simulations. These activities encompassed both traditional data analysis and an in-depth examination of data formats, which we will discuss in the following section.

Disk space

We made full use of the 520 TB Levante storage grant for intensive data comparison. This analysis focused on contrasting classic model output in GRIB2 format with a newer format, Zarr. The inherent chunking of the Zarr format in combination with state-of-the-art compression, significantly improved data access speed for users. Notably, these findings have influenced the NextGEMS project and continue to shape developments in the ICON output strategy.

Tape archive

We were allocated around 250 TB of archival space, which we've fully utilized to back up the original model output in GRIB2 format. In the coming weeks, we will coordinate with DKRZ to migrate this data to a long-term archive, where an equivalent amount of tape space is available.

References

Bao J., Stevens B., Kluft L. and Muller C., in prep: Intensification of tropical precipitation extremes from more organized convection

Ćorko et al., in prep: The representation of tropical deep convection in a hierarchy of global models - Evaluation of the tropical upper tropospheric cloudiness simulated by the convection permitting DYAMOND models