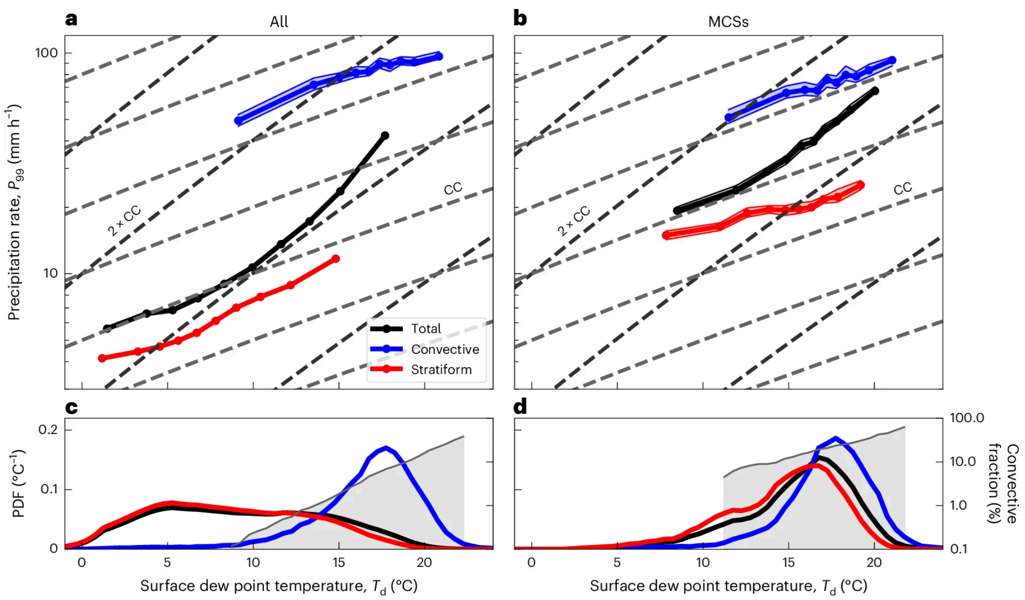
Report for DKRZ project bb1166 (Haerter)

Project: **1166**
Project title: **Cloud-cloud interaction in convective precipitation (INTERACTION) and DakE continuation**
Principal investigator: **Jan Haerter**
Report period: **2024-05-01 to 2025-04-30 (INTERACTION) [2024-07-01 to 2025-12-31 (DakE continuation)]**
During the report period above a number of computational research projects have been accomplished:

Da Silva and Haerter (2025), Nature Geoscience, employs a combination of numerical and observational approaches to test the hypothesis of the super Clausius-Clapeyron increase in thunderstorm precipitation with temperature. It arrives at the conclusion that, when probing convective-type precipitation intensities at high resolution, their scaling for extreme percentiles is in fact in line with the Clausius-Clapeyron relation. When studying superpositions of convective and stratiform precipitation, a statistical super-Clausius-Clapeyron increase is apparent. This paper addresses and seems to resolve a long-standing hypothesis which dates back to a seminal paper by Lenderink and van Meijgaard, Nature Geoscience, 2008. There, it was claimed that convection, by itself, shows an unexpected increase of approximately 14 percent per Kelvin. The current work refutes this hypothesis by a new combination of observational data.



Reproduction of Fig. 2 from Da Silva & Haerter, Nature Geoscience, 2025. The figure shows that both convective and stratiform extreme rainfall independently increase at 7 percent per Kelvin and that only their statistical superposition shows an apparent super-Clausius-Clapeyron increase of more than 7 percent per Kelvin.

Börner, Fiévet, Haerter (2025), Geophysical Model Development. Brings forward the *diuSST model* for the sea surface skin layer. This model constitutes a major step forward as it will allow us to model the response of the thermally active skin layer (<< 1m) within a high-resolution cloud resolving model, SAM. The traditional form of modeling this is through a relatively thick single surface layer which then produces a much too slow response to atmospheric processes due to its too high heat capacity. We expect more realistic numerical simulations from diuSST: we will assess, if mesoscale convective systems over the ocean can induce relatively large temperature variations at the sea surface due to precipitation freshwater lenses and storminess - inducing mixing.

Kruse, Fiévet, Haerter (2025), Journal of Advances in Earth System Modeling. This paper was able to capture the effect of hysteresis in a simple toy model for the diurnally aggregated state. The paper compares the toy model with a high-resolution cloud resolving simulations using SAM. The main finding is that diurnally induced mesoscale convective systems over continental areas can give rise to persistent dry areas that do not receive precipitation over the course of several weeks. Such dry areas are compensated by persistently moist areas that precipitate heavily. The paper addresses the question of whether such disturbances could be advected over oceanic areas - where surface temperature variations are often much smaller - and even persist there. This is indeed found in a form of hysteresis effect. The implications for tropical cyclogenesis will be explored in subsequent work.

References (all within bb1166)

Da Silva, N.A., Haerter, J.O. Super-Clausius–Clapeyron scaling of extreme precipitation explained by shift from stratiform to convective rain type. *Nat. Geosci.* (2025). https://doi.org/10.1038/s41561-025-01686-4

Börner, Reyk, Jan O. Haerter, and Romain Fiévet. "DiuSST: a conceptual model of diurnal warm layers for idealized atmospheric simulations with interactive sea surface temperature." *Geoscientific Model Development* 18.5 (2025): 1333-1356.

Kruse, I. L., R. Fiévet, and J. O. Haerter. "Tipping to an aggregated state by mesoscale convective systems." *Journal of Advances in Modeling Earth Systems* 17.3 (2025): e2024MS004369.

Hoeller, Jannik, et al. "U-net segmentation for the detection of convective cold pools from cloud and rainfall fields." Journal of Geophysical Research: Atmospheres 129.1 (2024): e2023JD040126.

Hoeller, Jannik, Jan O. Haerter, and Nicolas A. Da Silva. "Characteristics of station-derived convective cold pools over equatorial Africa." Geophysical Research Letters 51.6 (2024): e2023GL107308.

Hoeller, Jannik, Romain Fiévet, and Jan O. Haerter. "Detecting cold pool family trees in convection resolving simulations." Journal of Advances in Modeling Earth Systems 16.1 (2024): e2023MS003682.

Da Silva, Nicolas A., and Jan O. Haerter. "The precipitation characteristics of mesoscale convective systems over Europe." Journal of Geophysical Research: Atmospheres 128.23 (2023): e2023JD039045.

Vraciu, Cristian V., Irene L. Kruse, and Jan O. Haerter. "The role of passive cloud volumes in the transition from shallow to deep atmospheric convection." Geophysical Research Letters 50.23 (2023): e2023GL105996.

Haerter, Jan O., and Romain Fiévet. "Precipitation resonance for an idealized ITCZ model." Authorea Preprints (2022), under review

Jensen, Gorm Gruner, Romain Fiévet, Jan O. Haerter. “The diurnal path to persistent convective self-aggregation”, Journal of Advances in Modeling Earth Systems (2022) 14 (5), e2021MS002923

Niehues, Jakob, Gorm Gruner Jensen, and Jan O. Haerter. "Self-organized quantization and oscillations on continuous fixed-energy sandpiles." Physical Review E 105.3 (2022): 034314.

Nissen, Silas Boye, and Jan O. Haerter. "Circling in on Convective Self-Aggregation." Journal of Geophysical Research: Atmospheres 126.20 (2021): e2021JD035331.

Haerter, Jan O., Bettina Meyer, and Silas Boye Nissen. "Diurnal self-aggregation." npj Climate and Atmospheric Science 3.1 (2020): 1-11.