Project: **1163**

Project title: **C2Phase: Closure of the Cloud Phase**

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Report period: **2022-05-01 to 2023-04-30**

Text: Maximum of two pages including figures. Reports for joint projects may be longer.

Subproject A: Statistical emulation for untangling microphysical uncertainties in hail storms

The prediction of hail storms is highly uncertain and we investigate relative contributions from aerosols, microphysics and environmental conditions to the uncertainty in hail- and precipitation-related parameters. We generated a perturbed parameter ensemble (PPE) using the ICON-ART model on convection permitting scale for one selected hail event on July 28 in 2013 over the Neckar Valley in Southwest Germany. Six parameters were jointly perturbed, namely the CCN and IN concentration, riming efficiency of graupel and hail, the stability and the vertical wind shear. We used the Latin hypercube sampling to distribute the parameters well-spaced in the six dimensional parameter uncertainty space.

Compared to the previously reported results, we have extended our PPE to now in total 225 members for statistically more robust results. Statistical emulation and clustering was used for the analysis. Figure 1 shows the contribution of three of the six perturbed parameters to surface hail, which is mainly influenced by the CCN concentration. However, within clusters of similar geographical distributions of total precipitation (obtained by k-means clustering), stability also plays a role. Furthermore, it is evident that the wind shear appears to determine the separation into the clusters.

A publication on these results is currently in preparation.

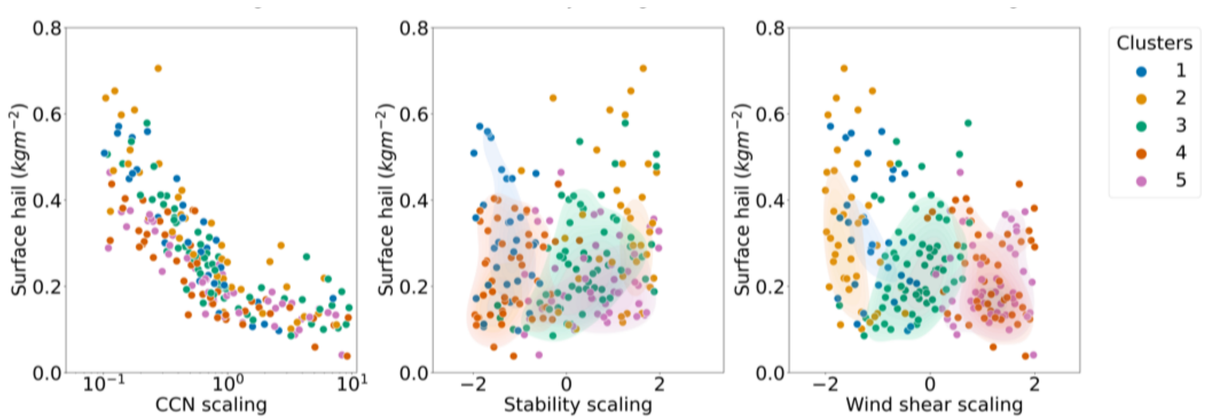

Figure 1: Scatter plots of surface hailin dependency of the perturbed parameters CCN, atmospheric stability and wind shear. Each point represents one ensemble member of our perturbed parameter ensemble (225 members). We take the mean over the region used for the cluster analysis. The colours indicate the five determined precipitation clusters.

Subproject B: Cloud types over the Arctic Ocean and Southern Ocean (DYAMOND dataset)

In a recent publication *(Dietel et al., 2023, https://doi.org/10.5194/egusphere-2023-2281, accepted for publication in Atmospheric Chemistry and Physics),* we have shown (based on analysis of satellite observations) that the cloud phase of high-latitude low-level clouds depends on the underlying surface, and that for a given cloud top temperature clouds over sea ice are more likely to consist of supercooled liquid than of ice. We have investigated in how far this behaviour is reproduced by the DYAMOND models. Our findings so far show that several different configurations of the ICON model produce the opposite behaviour (more liquid above the open ocean). Further investigations on the causes are ongoing.

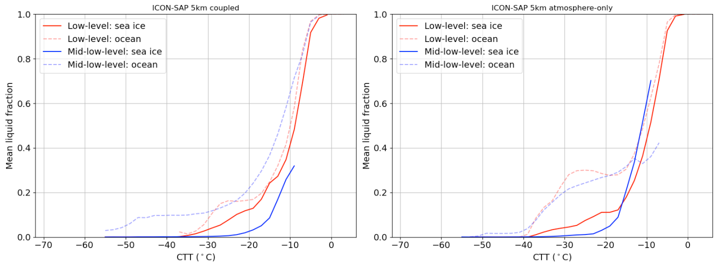

Figure 2: Supercooled liquid fraction as a function of cloud top temperature in two different ICON configurations from the DYAMOND winter dataset.

Subproject C: Secondary ice processes

Multiple mechanisms have been proposed to explain secondary ice production (SIP), and SIP has been recognized to play a vital role in forming cloud ice crystals. However, most weather and climate models do not consider SIP in their cloud microphysical schemes. In this study, in addition to the default rime splintering process (RS), two SIP processes, namely shattering/fragmentation during freezing of supercooled rain/drizzle drops (DS) and breakup upon ice-ice collisions (BR), were implemented into the two-moment cloud microphysics scheme of ICON. Besides, two different parameterization schemes for BR were introduced.

We have extended our simulations of the previous project phases by more case studies and sensitivity experiments. The results have recently been published in a journal article:

Han, C., C. Hoose, and V. Dürlich, 2024: Secondary ice production in simulated deep convective clouds: A sensitivity study. J. Atmos. Sci., https://doi.org/10.1175/JAS-D-23-0156.1, in press.

In the series of sensitivity experiments, we have investigated how SIP impacts cloud microphysics and cloud phase distributions in warm-based deep convective clouds developed in the central part of Europe. Simulation results revealed that cloud microphysical properties were significantly influenced by the SIP processes. Ice crystal number concentrations (ICNCs) increased up to more than 20 times and surface precipitation was reduced by up to 20% with the consideration of SIP processes. Interestingly, BR was found to dominate SIP, and the BR process rate was larger than the RS and DS process rates by 4 and 3 orders of magnitude, respectively. Liquid pixel number fractions inside clouds and at the cloud top decreased when implementing all three SIP processes, but the decrease depended on the BR scheme. Peak values of ice enhancement factors (IEFs) in the simulated deep convective clouds were 10^2 to 10^4 and located at −24 °C with the consideration of all three SIP processes, while the temperature dependency of IEF was sensitive to the BR scheme. However, if only RS or RS and DS processes were included, the IEFs were comparable, with peak values of about 6, located at −7 °C. Moreover, switching off the cascade effect led to a remarkable reduction in ICNCs and ice crystal mass mixing ratios.

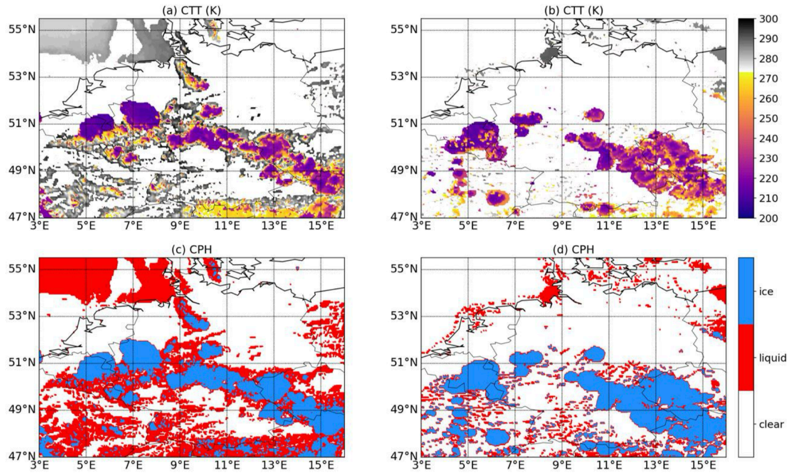

Figure 3: Spatial distributions of the retrieved cloud-top temperature (CTT) and cloud phase (CPH) at 13:00 UTC for the case with deep convective clouds over central Europe. The left panel shows the CLAAS-2 (Cloud property dAtAset using SEVIRI, edition 2) product and the right panel displays the reference simulation.