HD(CP)²

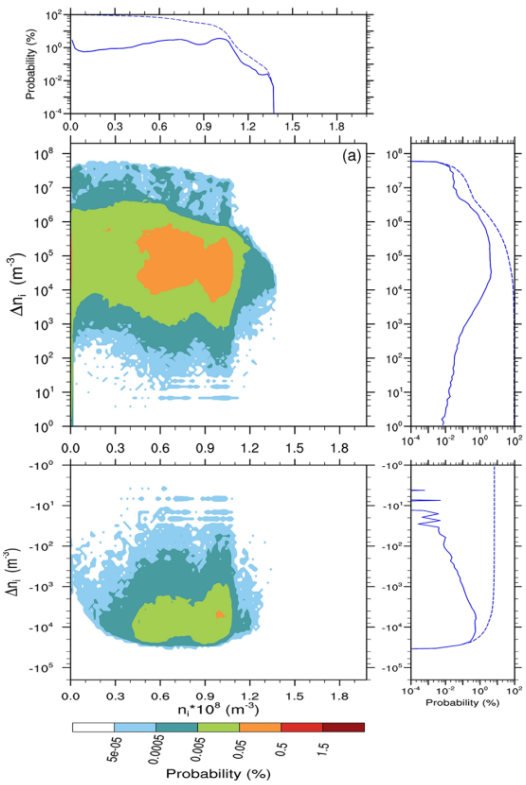
High definition clouds and precipitation
for advancing climate prediction

Project: 852
Project title: HD(CP)2 Diagnostics and ice clouds in ICON
Project leader: Dr. Ulrike Burkhardt
Report period: 01.01.2022 – 31.10.2022

HD(CP)² - S1 TP2 Kondensstreifenzirren (Verma b309131, Burkhardt b309022)

In the last year, we have further improved our parameterization for contrail ice formation within cirrus clouds and analyzed the effect of pre-existing cirrus ice crystals on contrail ice formation within cirrus. The work lead to the publication Verma and Burkhardt (ACP, 2022) and is part of the Ph.D. thesis of Pooja Verma that was concluded with the defense of her Ph.D. thesis in October 2022.

In the paper we analyzed the impact of pre-existing ice crystals on contrail formation within cirrus sampling a large range of natural cirrus properties. We have selected two very different cirrus clouds, one connected with a high-pressure situation over Germany (24th April 2013) and another connected with a frontal passage (26th April 2013).



We consider the effect of pre-existing cirrus ice crystals that are sucked into the engine and sublimate there, causing a change in the water vapor content of the plume. Furthermore, we consider the effect of cirrus ice crystals that get mixed into the plume and partially sublimate initially due to subsaturation in the plume (Kärcher et al., 2015), and once the plume reaches ice saturation, the available plume water vapor starts to deposit on the entrained cirrus ice crystals. The adjustment in the plume water vapor concentration due to sublimation and deposition of the entrained cirrus ice crystals has been approximated and included in the calculation of contrail formation conditions and ice nucleation. We found a significant change in the formation threshold temperature and therefore in the number of nucleated ice crystals in contrail when contrail ice crystals nucleate in a thick cloud (large ice water content and high ice number concentration) (Verma and Burkhardt 2022).

Figure 1: Joint probability distribution of ice crystal number concentration due to contrail ice nucleation, n_i, and its change due to the pre-existing cirrus ice crystals Δn_i, and the respective one-dimensional PDF (dashed)for current soot number emissions, $2.5*10^{15}$ kg-fuel^{-1} on the 26th April 2013 5 pm.

Furthermore, we have analyzed the impact of contrail ice formation within cirrus on the cirrus properties. We initialized real air traffic of the year 2006 (Wilkerson et al., 2010) over Germany. We found that, due to contrail ice formation within cirrus, the ice number concentration has been increased in the cirrus cloud and reaches value up to 3 orders of magnitude higher than the ice number concentration in the surrounding cirrus at flight altitudes (ambient temperature below 233.15 K in figure 2 (a, b)). Contrail ice formation within cirrus introduces many small ice crystals, much smaller than the ice crystals usually found in cirrus clouds outside the areas of fresh nucleation events. Therefore, after contrail ice formation within cirrus, size distribution of ice crystals in cirrus changes. We found that smaller mean volume diameter (~1 µm) of ice crystals appeared at flight levels after contrail ice formation within cirrus (figure 2(d)).

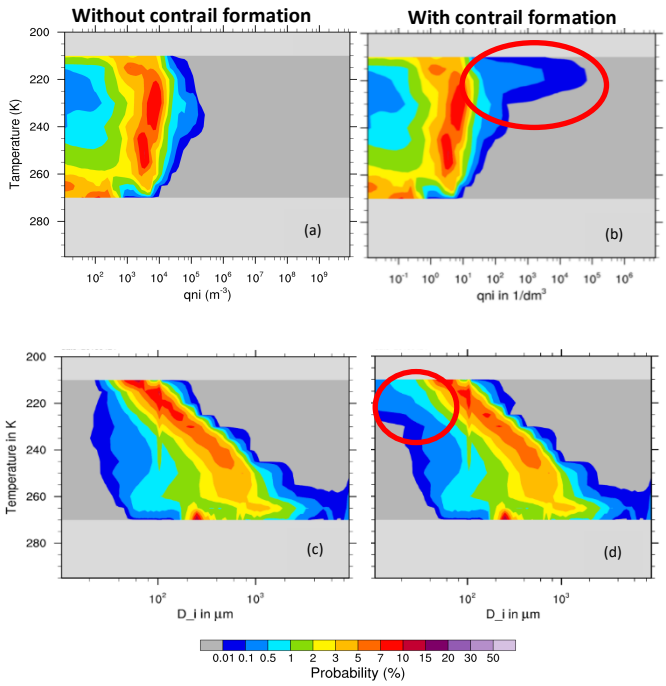


Figure 2: Frequency of occurrence of grid mean ice number concentration 'qni' (m^{-3}) (a, b) and mean volume diameter 'D_i' (µm) (c, d) in cloud on 24th April 2013 at 06 - 07 am. The first column shows properties of the undisturbed cloud. The last column shows the cloud properties including contrail induced disturbances after two hours of air traffic.

Since, we have improved the contrail formation parameterization, we need to repeat some of our longer simulations with improved parameterization to study the life cycle of the contrail perturbed cirrus for both synoptic conditions and analyze the impact on cirrus cloudiness. Those simulation will for the basis for our second publication. The analysis will be the same as already performed within the PhD thesis.

References:

Verma, P. and Burkhardt, U. "Contrail formation within cirrus: ICON-LEM simulations of the impact of cirrus cloud properties on contrail formation", *Atmos. Chem. Phys.*, 22, 8819–8842, https://doi.org/10.5194/acp-22-8819-2022, 2022.

Verma, P. "Simulating contrail formation within cirrus in the high-resolution ICON-LEM model". PhD thesis der Fakultät für Physik der Ludwig-Maximilians-Universität München, 2022.