Project:	**1262**
Project title:	**Impact of Aerosol on Cloud Microphysics, Phase Partitioning and Precipitation Formation**
Project lead:	**Dr. Fabian Senf (TROPOS)**
Allocation period:	**1.1.2023 - 31.12.2023**

Overview of planned work

Introduction: The DKRZ user project bb1262 supports research work in the DFG project PolarCAP, which is part of the DFG priority program PROM[1]. Within the framework of PolarCAP, intensive collaboration is taking place with the remote sensing scientists of TROPOS as well as with researchers from ETH Zurich. ETH is leading the renowned ERC research project CLOUDLAB [2], in which experiments are being conducted on supercooled liquid water clouds to better understand the nature of ice formation processes and primary ice production. This will make an important contribution to weather and climate research, as it is the uncertain partitioning of ice and liquid water in clouds that leads to large uncertainties in the prediction of precipitation and the determination of climate sensitivities. In the CLOUDLAB experiments, heated drones are flown into supercooled Swiss fog, where they initiate ice formation with the help of burning silver iodide flares (Miller et al., 2023). Downstream of the ignited flares, the properties of the ice formed will be studied using a variety of insitu and remote sensing methods (Henneberger et al., 2023). In order to infer process rates from the observables and to derive implications for atmospheric modeling, detailed cloud simulations with the spectral bin model SPECS are carried out by TROPOS to accompany the campaign.

Planned HPC Use: In utilization period, it was planned to perform COSMO-SPECS experiments for 4 seeding cases, hoping to achieve further successful seeding experiments by CLOUDLAB-PolarCAP in spring 2023. Target resolution is in the hectometer range. Experiments were planned in which the aerosol background conditions are to be varied, i.e. CCN and INP concentrations, as well as experiments in which the flare strength is successively increased. Together, 144 hours of COSMO-SPECS simulations were planned with an estimated computation time of 6000 node hours.

Overview of Resource Use

During the planned utilization period, a total of five users worked on the project, including one bachelor student and one doctoral student in addition to the actual project staff. This promoted the training of young scientists. More than 60 hours of COSMO-SPECS simulations were conducted so far. Of the 4800 node hours of resources "used up" so far, 2200 node hours (i.e. 45%) expired due to quarterly accounting. We believe that the utilization of project resources will improve considerably by the end of 2023. Insufficient resource usage was partly due to the fact that important implementations (flare functionality) were carried out and extensively tested in the first half of the utilization

[1] https://gepris.dfg.de/gepris/projekt/359922472?language=en
[2] https://cloudlab.ethz.ch/

period and thus the planned production runs were and are carried out in the second half of the year. Furthermore, the required memory was planned too tightly. This led to significant limitations. Prototype experiments with smaller domains and shorter runtimes were therefore used extensively to work out which diagnostics for the cloud simulations had to be mandatorily output in order to make the scientific exploitation as optimal as possible. Corresponding extensions were implemented in the model by means of predefined output variable groups.

Results Achieved in the Reporting Period

The CLOUDLAB-PolarCAP research consortium was able to celebrate successes during the 2022/23 winter campaign. The case base of successful seeding experiments was significantly expanded. With our first COSMO-SPECS seeding experiments, we focused on the exceptional case at 25 January 2023, on which three seeding experiments were subsequently carried out (see Fig. 6 in Henneberger et al., 2023). COSMO-SPECS was operated with a horizontal mesh size of just below 500 m and the silver iodide flare was ignited as a separate INP source for a period of about 6 min at a freezing temperature of -5 degrees Celcius. Considerably enhanced ice crystal concentrations result (Fig. 1). The subsequent ice crystal growth is simulated in detail by our spectral bin model. These results are very promising and we are currently in an extensive evaluation phase where we are closely linking to available observations. Some deficiencies have already been discovered: INPs are still not efficient enough for realistic ice production. Moreover, our sensitivity experiments for changes in the background aerosol concentrations have unfortunately been erroneous and need to be fixed and repeated.

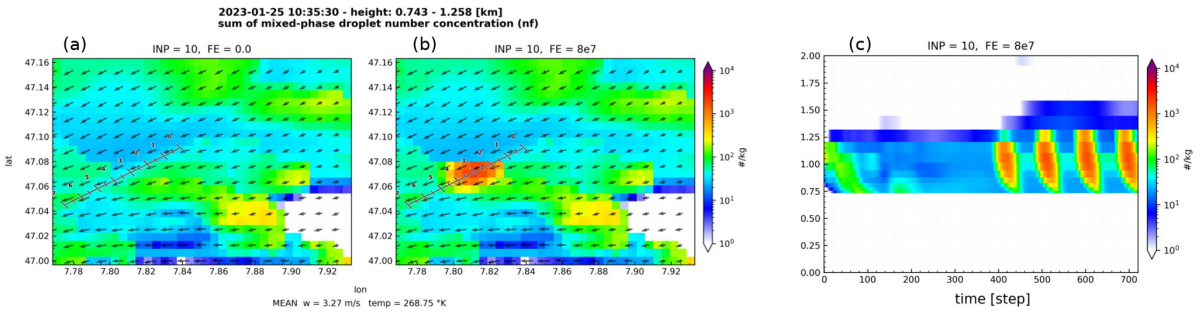

Figure 1: Ice crystal concentrations shown as spatial distributions for reference (a) and seeding (b) and as timeseries for seeding only (c). Enhanced ice crystal concentrations (red colors) stick out for the seeding cases.

References

Henneberger, J., and Coauthors, 2023: Seeding of supercooled low stratus clouds with a uav to study microphysical ice processes - an introduction to the cloudlab project. *Bull. Amer. Meteor. Soc.*, doi:https://doi.org/10.1175/BAMS-D-22-0178.1.

Miller, A. J., and Coauthors, 2023: Two new multirotor uavs for glaciogenic cloud seeding and aerosol measurements within the cloudlab project. *Atmos. Meas. Tech. Discuss.*, **2023**, 1–30, doi:10.5194/amt-2023-157, URL https://amt.copernicus.org/preprints/amt-2023-157/.