Project:	**1262**
Project title:	**Impact of Aerosol on Cloud Microphysics, Phase Partitioning and Precipitation Formation**
Project lead:	**Dr. Fabian Senf (TROPOS)**
Allocation period:	**1.1.2024 - 31.12.2024**

Overview on the Project

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., 2024). Downstream of the ignited flares, the properties of the ice formed are 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.

Overview on Planned and Realized Resource Use

In utilization period, it was planned to perform COSMO-SPECS experiments for three already studied seeding cases (exp. set A). In addition, it was planned to expand investigations to cases with different seeding temperatures (set B), to warm cloud seeding (set C) and to different background wind conditions (set D). Target resolution is in the hectometer range. Together, COSMO-SPECS simulations were planned with an estimated computation time of 6000 node hours.

Up to the time of the writing, the project consumed a total of about 5109 node hours with 1771 node hours being expired due to quarterly accounting. Suboptimal resource usage was partly due to the fact that COSMO-SPECS was not able to run at the highest resolution due to a software bug that was resolved in the second half of the year allowing for more efficient scaling. A new domain was established with the measurement site at the center, and vertical analysis was conducted using grid-point-output (meteogram). Considerable compute time was spent on bug identification, scaling experiments and the subsequent simulations of the high resolution domain. The project bb1262 had four actively contributing members in 2024 of which 50% were Early Career Scientists.

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

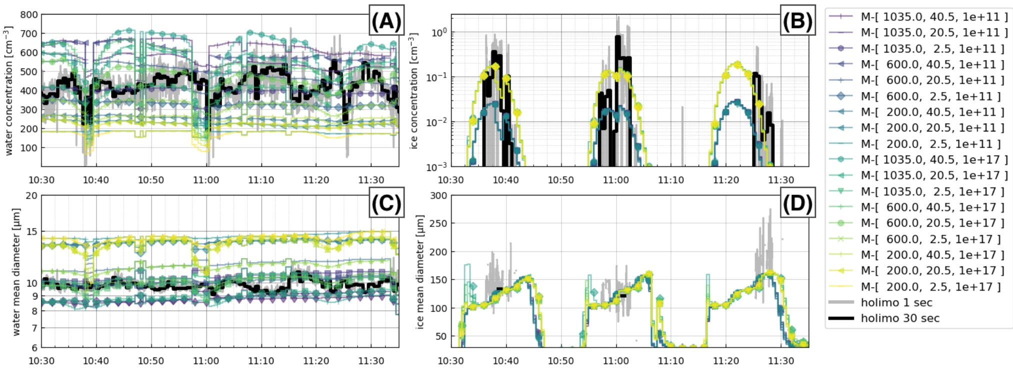

Figure 1: Time series of COSMO-SPECS model bulk variables from 25. January 2023 compared to HOLIMO in-situ observations (A-D). Where colored marker lines ‘M[X Y] Z‘ correspond to variations in initial CCN number concentration and flare INP. Light blue and dark blue solid lines correspond to HOLIMO measurements of 1 s time resolution and 30 s time resolution, respectively.

Results Achieved in the Reporting Period

Scaling experiments of the COSMO-SPECS model on Levante were conducted to determine the feasibility of running the model at spatial resolutions down to 100 m. The model demonstrated good scaling performance up to 40 nodes, with diminishing returns beyond this point. Specifically, the microphysics calculations scaled almost ideally with an increased number of nodes due to our load balancing functionality (FD4 library), whereas output writing emerged as a significant bottleneck, limiting the overall performance. Corresponding adjustments in 3d output frequency and the extended use of meteogram output were applied as solution. The main production work concentrated on three subsequent cloud seeding cases at January 25, 2023 (set A). Two setups (size: 16 km x 18 km) with a horizontal resolution 400 m and 100 m and a vertical resolution from 9 m to 520 m over 100 vertical levels were utilized. The team worked on improving the reference state characterization, comparing model results with in-situ observations and remote sensing observations (see Fig. 1). Experiments were conducted in which the aerosol background conditions have been varied, i.e. CCN and INP concentrations, as well as experiments in which the flare strength was successively increased. We like to emphasize that both the bulk variables and the model spectra of liquid and frozen particles show good agreement to the in-situ observations (from holographic imagery). However, the model requires an exaggerated amount of flare particles to match the reduction of cloud water and the increase of ice crystal number and size. Overall, the progress in model development, data analysis and collaborative research efforts in 2024 is very satisfactory even though the further planned experiments (set B-D) could not be carried out.

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, 2024: Two new multirotor uncrewed aerial vehicles (uavs) for glaciogenic cloud seeding and aerosol measurements within the cloudlab project. *Atmospheric Measurement Techniques*, **17 (2)**, 601–625, doi:10.5194/amt-17-601-2024, URL https://amt.copernicus.org/articles/17/601/2024/.