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Detailed spectral-bin microphysics simulations of primary ice formation in artificially seeded supercooled stratus clouds

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The PolarCAP project aims to better understand the interplay between aerosol and cloud-microphysical processes by investigating the evolution of the ice phase under slightly supercooled conditions (T > −10 ℃) within a thermodynamically and aerosol-controlled environment, employing radar polarimetry, holographic imagery and spectral-bin modelling. In collaboration with the CLOUDLAB project at the ETH Zurich, PolarCAP investigates the development of an artificially initiated ice phase
within supercooled stratus clouds. Utilising cloud seeding with silver iodide, CLOUDLAB initiates the freezing process of cloud droplets. The subsequent evolution is monitored using in-situ measurements and ground-based cloud remote sensing tools. The collaboration has yielded a unique dataset, incorporating observations from the Leipzig Aerosol and Cloud Remote Observations System (LACROS) and observations from CLOUDLAB in tandem with data from the cloud-resolving spectral-bin microphysics model COSMO-SPECS.

We present a comparative evaluation between observational data and simulations of the spectral-bin model COSMO-SPECS (CS) featuring an artificial particle source. A multitude of ensemble CS model runs were performed on two different mesh sizes, with horizontal resolution of ~400 m and ~100 m in various configurations. First, we demonstrate the CS model's ability to reproduce observed cloud responses, providing insights into ice nucleation and growth processes, in particular the Wegener-Bergeron-Findeisen (WBF) process. During the seeding experiments, observations show simultaneous decreases in cloud droplet concentrations alongside increases in ice crystal concentrations, including periods where cloud droplets were entirely depleted. Our findings suggest that significant amounts of flare INP are required to replicate observed ice crystal concentrations and cloud droplet reductions. This could indicate that the model scheme may be unsuited for deriving immersion INP concentrations from flare particle emissions. Second, the measured ice crystal sizes and growth rates, are compared to the CS output. This comparison revealed discrepancies in ice crystal size distributions, highlighting potential model biases due to parametrizations of ice crystal growth. Furthermore, the comparison revealed insights into the importance of spatial resolution of the CS model.

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