New insights into Arctic mixed-phase clouds from airborne and EarthCARE observations

Lars van Gelder[1], Pavlos Kollias[2,3], Mario Mech[1], Lukas Pfitzenmaier[1], and Susanne Crewell[1]

[1]Institute for Geophysics and Meteorology, University of Cologne, Germany
[2]School of Marine and Atmospheric Sciences, Stony Brook University, New York, US
[3]McGill University, Montreal, Quebec, Canada

Low-level Arctic clouds, especially mixed-phase clouds, are key drivers of regional climate and Arctic amplification, yet their microphysical and dynamical properties remain difficult to observe in data-sparse regions. EarthCARE offers new opportunities to address this observational gap; however, its measurements require validation using independent reference data. As a contribution to these validation activities, the Polar 5 research aircraft of the Alfred Wegener Institute has been equipped with an EarthCARE-like instrument suite and operated during the COMPEX-EC (Clouds over cOMPlEX environment – EarthCARE) in April 2025 from Kiruna, Sweden. During seven research flights, we collected more than 5 hours of along-track airborne radar measurements collocated with EarthCARE overpasses, covering diverse Arctic conditions from marine cold-air outbreaks (CAO) over the Norwegian Sea to cloud fields over northern Scandinavia.

For moving platforms, such as aircraft, corrections addressing horizontal and vertical motion, as well as attitude, need to be applied to some of the measurements. Hereby, the Doppler velocity is especially challenging, and this is further complicated by the installation of the W-band Microwave Radar/radiometer for Arctic Clouds (MiRAC) on Polar 5 in a belly pod with a 25° inclination under the aircraft, which enhances the complexity. MiRAC is complemented by a microwave radiometer, an Airborne Mobile Aerosol Lidar for Arctic research (AMALi), spectral and broadband radiative sensors, and dropsondes.

The collected data provide a unique basis for evaluating EarthCARE cloud products, with a particular focus on cloud geometric properties and vertical cloud structure. Cloud-top heights are derived from AMALi and MiRAC and compared to spaceborne retrievals from EarthCARE ATLID and CPR across different Arctic cloud regimes. We exploit the complementary sensitivities of lidar and radar to assess the detectability of thin liquid-topped clouds and mixed-phase cloud layers. Dropsondes released during EarthCARE overpasses provide thermodynamic and wind profiles that support the interpretation of observed cloud structures and precipitation occurrence. Beyond EarthCARE validation, the dataset contributes to an enhanced understanding of Arctic cloud vertical structure and its relevance to precipitation development under different synoptic conditions.

Ongoing work aims to extend the analysis towards Doppler-based interpretations of cloud dynamics.

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