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Advancing the understanding of Arctic mixed-phase clouds and snowfall: Insights from recent airborne campaigns

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Low-level Arctic clouds play a crucial role in the Arctic climate system, influencing radiative forcing and Arctic amplification. These clouds frequently exist in a mixed-phase state, where the coexistence of supercooled liquid and ice particles significantly impacts cloud lifetime and precipitation processes. However, distinguishing between ice and liquid components remains challenging, particularly in remote Arctic regions. Additionally, snowfall estimates suffer from significant uncertainties due to observational limitations, particularly during marine cold-air outbreaks (CAOs).
To address these challenges, multiple airborne campaigns have been conducted in the framework of the Collaborative Research Center "Arctic Amplification" (AC)³ to improve the understanding of Arctic clouds. Here, we focus on observations made on-board the AWI Polar aircraft equipped with active and passive remote sensing instruments, such as high-resolution radar measurements and microwave radiometers, to characterize better the structure and evolution of mixed-phase clouds and shallow precipitation. These campaigns provide valuable datasets for assessing snowfall and investigating precipitation processes. Comparisons with in situ observations within coordinated flights by a similar aircraft allow the assessment of the liquid water path (LWP) and ice water path (IWP) in clouds.
The upcoming COMPEX-EC campaign in April 2025, based in Kiruna, Sweden, aims to enhance our understanding of low-level Arctic clouds through high-resolution observations. A key objective is to derive the vertical hydrometeor distribution and validate EarthCARE satellite measurements. By leveraging high-resolution radar reflectivity and Doppler velocity data, the campaign will focus on characterizing mixed-phase clouds and distinguishing between ice and liquid hydrometeors under diverse atmospheric conditions. Additionally, COMPEX-EC provides a unique opportunity to assess the quality of EarthCARE’s performance and validate its measurements in the Arctic. The comparison with airborne observations helps identify the strengths and limitations of EarthCARE's performance, particularly its resolution and blind zone. These findings are important for the interpretation of Arctic-wide EarthCARE measurements concerning Arctic cloud microphysics and precipitation processes, ultimately improving climate and weather models.