Airborne W- and G-band radar observations of Arctic mixed-phase clouds and in-cloud water vapor

Arctic Amplification is most evident in the rise of the near-surface air temperature observed in the last decades and is at least twice as strong as the global average. The mechanisms behind that are widely discussed. Many processes and feedback mechanisms are poorly understood, especially regarding the role of clouds and low-level water vapor. Direct observations are needed to increase the understanding of the Arctic water cycle and to improve the representation of the components and processes in numerical models, but they are barely available. Airborne platforms with state-of-the-art cloud remote sensing instrumentation can provide such heavily needed observations even in remote locations. Especially aircraft equipped with single- or multi-frequency radars can provide helpful information on the vertical distribution of in-cloud liquid and ice, precipitation amount and type, and micro-physical properties.

Within this contribution, we will present observations and results from various Arctic aircraft campaigns conducted during the last years with the polar research aircraft of the Alfred Wegener Institute, focusing on the atmospheric water cycle components and their inherent processes. During four campaigns flown out of Svalbard with a W-band FMCW Doppler radar on board, Arctic mixed-phase clouds in marine cold air outbreaks and their representation in satellite observations and models have been investigated. The high temporal and vertical resolution of the radar allowed (i) a detailed specification of the limitations of spaceborne radar and (2) a novel characterisation of CAO which enables statistical evaluation of numerical models. Studies on in-cloud water vapor profiles with a novel and unique Differential Absorption Radar (DAR) G-band FMCW Doppler radar have been recently performed. The G- and the W-band radars have been operated in a dual belly pod, allowing studies on cloud processes by investigating the dual-wavelength ratio information.

Recently, the W-band radar was used in the spring of 2025 for EarthCARE satellite validation measurements. Several research flights with more than 30 flight hours were performed from Kiruna, Sweden, to evaluate the EarthCARE instruments in Arctic conditions.