Airborne remote sensing observations of Arctic low-level clouds and precipitation during cold air outbreaks

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In cold air outbreaks (CAOs), cold and dry air flows from the central Arctic southward, which often leads to extreme weather conditions at mid-latitudes. Roll convection in the boundary layer is already triggered within the marginal sea ice zone. During the air-mass transformation, this roll convection leads to cloud formation within several 100 km away from the sea ice edge along so called streets. Mixed-phase processes and extreme surface heat fluxes play an important role in the air-mass transformation. Understanding air-mass transformation is very important to accurately represent them in weather and climate models. However, only few detailed observations of cloud macro- and microphysical characteristics during CAOs from the marginal sea ice zone along their trajectory over open ocean exist yet.

Our study investigates cloud rolls over the open ocean and sea ice west of Spitsbergen using airborne remote sensing measurements obtained by the Microwave Radar/radiometer for Arctic Clouds (MiRAC) and Airborne Mobile Aerosol Lidar for Arctic research (AMALi). We focus on two CAO events (1st and 4th April 2021) that took place during the HALO–$(AC)^3$ campaign conducted in March and April 2021. Both times the POLAR 5 aircraft flew several legs along the same track perpendicular to the cloud streets crossing the sea ice edge several times to allow a quasi-Lagrangian perspective. This allows an investigation of the air masses with time and with distance to the sea ice edge. In general, the boundary layer deepens with distance to the sea ice edge, thus cloud top height increases, and the convection develops to a cell convection. Hence, our analysis resolves the development of the roll convection. Dropsondes serve information of the thermodynamic state of the lower atmosphere, whereas the remote sensing observations allow for a geometrical and microphysical analysis of cloud streets. In-situ measurements from the POLAR 6 aircraft, which flew collocated with P5 but inside the clouds, give additional information on aerosol number concentrations and droplet size distributions.