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Advancements in Cold Cloud Physics: Insights from a Decade of Airborne In-Situ Measurements with the PHIPS Instrument

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Airborne in-situ measurements provide a valuable opportunity to measure ice cloud properties in their natural atmospheric contexts, significantly contributing to our understanding of complex atmospheric processes. Traditional in-situ measurement techniques, relying on forward scattering, shadowgraphs or holography, have provided valuable insights into cloud particle size information and shape. However, finding answers to unresolved research questions often requires alternative and more advanced measurement technologies.

In this talk, we discuss one of those more advanced airborne instruments, a single-particle cloud imager and nephelometer (PHIPS), and review its first decade of airborne operations. PHIPS was intended to unravel the link between ice crystal microphysics and angular light scattering properties in cirrus clouds on a single particle basis. We demonstrate how the combination of angular scattering function measurements with simultaneous in-situ microscopy can be used to develop new parameterisations of ice cloud single-scattering properties for radiative transfer models. Furthermore, we explore the distinctions between these observational-based parameterisations and conventional parameterisations assuming idealised ice crystal shapes.

The single-particle light scattering function, detected with high enough angular resolution, emerges as a potent tool to distinguish between spherical and aspherical particles. Consequently, such measurements could be used to reliably discriminate hydrometeor phases in mixed-phase clouds. We illustrate how this method provides new insights into the ice formation via secondary ice processes in Southern Ocean boundary layer clouds. Additionally, we present first attempts to evaluate parameterisations for secondary ice processes in numerical models (CAM6 and CM1) based PHIPS observations.

Our results underscore the necessity of airborne in-situ measurements and more advanced technologies in improving our understanding of fundamental ice cloud physics. This leads to more realistic parameterisations of microphysical processes as well a radiative properties of ice and mixed-phase clouds to be used in future climate and weather predictions.