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Ice particle detection in clouds using a high-speed Particle Phase Discriminator

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Mixed-phase clouds (MPCs), composed of both liquid droplets and ice crystals, play a crucial role in the global radiation budget. Yet, a reliable detection of liquid and ice cloud fraction remains difficult. This in turn hinders a complete understanding of the complex microphysical processes that occur within these clouds, and ultimately renders estimation of the radiative properties of MPCs difficult. Current devices are either only capable of counting the number of particles of different sizes without discriminating phase or cannot resolve to small enough scales (Baumgardner et al, 2011). However, detection of ice particle fraction down to particle sizes at the micrometer scale is critical. Here, we present a new instrument, the high-speed Particle Phase Discriminator (PPD-HS), significantly reducing shortcomings of earlier devices.

PPD-HS sizes particles by passing a continuous laser beam (similarly to commercial Optical Particle Counters) and discriminates their phase by analyzing scattering patterns of forward scattered light. Compared to PPD-2K presented by Vochezer et al. (2016), our new instrument reduces the information collected per particle, used for phase discrimination, and thus allows for an increased detection rate of cloud particles.
Phase discrimination is achieved by evaluating the spatial symmetry of the scattering pattern, allowing for classification of spherical cloud droplets and aspherical ice crystals. Here we present an in-depth analysis of instrumental performance.

The phase discrimination potential of PPD-HS is determined through a suite of laboratory experiments, using particles with well-controlled properties. These include spherical and aspherical particles covering a size range from approximately 1 to 15 µm. Our results show that PPD-HS detects particles larger than approximately 1 µm in diameter and reliably discriminates ice crystals from other cloud particles for particle size > 3 µm, providing the capabilities to detect freshly nucleated ice in MPCs.
In a second round of experiments, we coupled PPD-HS to the Horizontal Ice Nucleation Chamber (HINC), a Continuous Flow Diffusion Chamber (CFDC). HINC allows us to mimic formation of real cloud hydrometeors and assess the performance of PPD-HS to determine the hydrometeor phase under atmospherically relevant MPC conditions. Results from such experiments will be presented to assess the performance of PPD-HS in discriminating accurately the liquid and ice fractions formed in HINC. These will help us to evaluate whether PPD-HS could improve our ability to identify ice and water cloud fractions in the real atmosphere.

Significance statement

A new device, the high-speed Particle Phase Discriminator (PPD-HS), is presented that allows to discriminate liquid droplets from ice crystals under mixed-phase cloud conditions. We evaluate the performance of PPD-HS using a suite of well controlled laboratory experiments with well characterized particles.

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