

Abstract

Deficiency in understanding some key cloud-related processes is the major source of uncertainty in weather prediction, climate science, and atmospheric circulation modeling. Clouds are predominantly composed of water droplets. The size distribution of these droplets is a crucial parameter for quantitative microphysical characterization of clouds. It is indispensable for studying cloud lifetimes, radiative effects, and precipitation formation.

The in situ measurements are crucial for cloud microphysical research as they provide direct experimental access to individual droplets in a given sample volume. Shadowgraph imaging stands out as a relatively inexpensive yet highly effective optical method for in situ sampling of hydrometeors. It performs direct measurements of particles/droplets by capturing shadow images of them.

In this study, a commercial shadowgraph instrument, VisiSize D30 (hereafter called “VisiSize”), originally designed for characterization of industrial sprays, was adapted to in situ atmospheric measurements. The cloud microphysical properties, such as the droplet size distribution (DSD), droplet number concentration (DNC), and liquid water content (LWC) were measured by the VisiSize.

First, a series of laboratory tests were conducted using polydisperse cloud-like water droplets. A suitable correction method was developed to improve estimations of droplet number concentration and size distribution. The minimum droplet diameters providing uniform detection were obtained. Then, the sizing accuracy of VisiSize was verified using a monodisperse droplet generator while the effects of collisions and evaporation of generated droplets

were also observed during the lab experiments.

Next, a series of field experiments were performed at Umweltforschungsstation Schneefernerhaus (UFS), an environmental research station in the German Alps. While turbulent orographic clouds were passing the UFS, the VisiSize was measuring the size and velocity of cloud droplets together with a Phase Doppler Interferometer (PDI) device. A comparison of the results after applying modifications to the built-in software algorithms showed a reasonable agreement regarding the droplet sizing and velocimetry between VisiSize D30 and PDI for diameters larger than $13\text{ }\mu\text{m}$. However, discrepancies were observed concerning the droplet number concentration results, especially in smaller sizes. Further investigation by applying appropriate filters to data has allowed the attribution of discrepancies to two phenomena; different optical performance of the sensors regarding small droplets, and high turbulent velocity fluctuations relative to the mean flow, which results in an uncertain estimate of the volume of air passing through the PDI probe volume.

Finally, the VisiSize was utilized alongside an optical laser disdrometer, "OTT Parsivel²", to perform simultaneous precipitation measurements during different weather events in Warsaw. Disdrometers, as the common tools for measuring DSD of rainfall, face serious challenges in the drizzle mode (small drop size ranges). The capability of VisiSize to accurately measure a broad range of droplet sizes, especially drizzle drops, was used to prevent the DSD truncation and acquire more precise results.

In general, the VisiSize D30 shadowgraph instrument was successfully applied to cloud microphysical measurements. It performed satisfactorily under windy, cloudy, and humid weather conditions. Moreover, it could be shown that the VisiSize, itself, can not only be used for direct measurement of hydrometeors, but also can be considered as a reliable tool to verify new droplet/particle sizing systems in atmospheric physics.