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A holographic improvement to traditional Optical Array Probes

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Optical Array Probes have been used to measure cloud droplets and ice crystals in the size range of $\sim$10 μm up to $\sim$1 cm for about the last four decades. In this type of instrument, particles are swept past a focused laser sheet imaged onto a linear diode array. The resulting image has a single spatial axis and a time axis and thereby has shadowgraphs of the particles swept through and can then infer their size and shape, and therefrom size distributions, liquid water content, ice water content, and so on. One weakness inherent in the method is the difficulty in measuring small particles ($\sim$10 to 200μm in size) which appear out of focus or are not detected at all, depending on how far from the focus of the laser sheet they appear in the sensitive region. Out-of-focus small particles appear as a diffraction rings or doughnuts making the particles appear large than they actually are. Also the region in which the instrument is sensitive to small particles or depth-of-focus region is difficult to estimate making number concentrations and size distributions difficult to measure.

On the other hand, holographic sample volumes are well defined as the sensitive region spans the entire area in which particles appear and the particles appearing in the holograms are reconstructed to their focus position. I.e. there is no depth-of-focus problem and the particles are sized in their focus position. Current holographic cloud particle probes use two-dimensional cameras that take snapshots of cloud particles having two spatial dimensions. These probes have also been high-resolution which requires high-performance servers to do the reconstruction and particle finding meaning the results of the measurements come long after the holograms are made. Of great advantage might be a low-resolution holographic probe with a spatial axis and a time axis with real-time results.

Shown is that simple modifications to existing optical array probes such as a collimated laser sheet and a grayscale sensor, and a simple low-resolution holographic reconstruction technique can be used to remove the depth of focus and the over-sizing problem from an optical array probe of similar configuration. It is hypothesised that for low enough resolution and flight speeds, the hologram reconstruction and particle finding algorithm could be implemented realtime on an FPGA. It is shown that only a few grayscales are necessary to make holograms of sufficient quality. Discussed is the sensitivity of smallest detectable particle size and sample volume depth are to the detector size. Also discussed is that one would obtain a rough estimate of the third spatial position of small particles in the sample volume resulting in a better resolved view of the structure of the cloud.