Long-exposure digital holography applied to study mixing at the laboratory analogue of cloud top

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Introduction

Clouds are one of the most important components of the climate system. Insufficient understanding of the physical processes occurring inside them significantly raises the uncertainty of weather and climate predictions [1]. For instance, microscale details of mixing with clear air at the cloud edge affect droplet size distribution which determines optical properties of the cloud [2]. Thus, development of reliable measurement techniques which allow for tracking individual cloud droplets in the course of their evolution poses a challenge for modern cloud physics.

Experiment

An artificial cloud consisting of water droplets with mean diameter of 13 μm, mean concentration of about 500 cm^{-3} was produced inside a unique laboratory chamber. The cloud was capped from above with a thermodynamically stable dry air layer. The motion of droplets in a mixing event at the cloud top was observed in a volume of 1 cm^3 with an optical system employing long-exposure digital in-line holography [3]. The main advantage of the designed method is the simultaneous estimation of droplets size, position and 2 components of velocity based on a single hologram recorded with a CCD camera.

Results

The variability of droplets spatial distribution, size distribution and horizontal velocities at the scale of several millimeters was revealed in the cloud top region (fig. 1). Application of a custom-developed supervised machine learning scheme for analysing objects in a reconstructed volume significantly improved particle detection rate. Further adavances might lead to the construction of an airborne instrument for investigation of similar phenomenon in natural clouds.

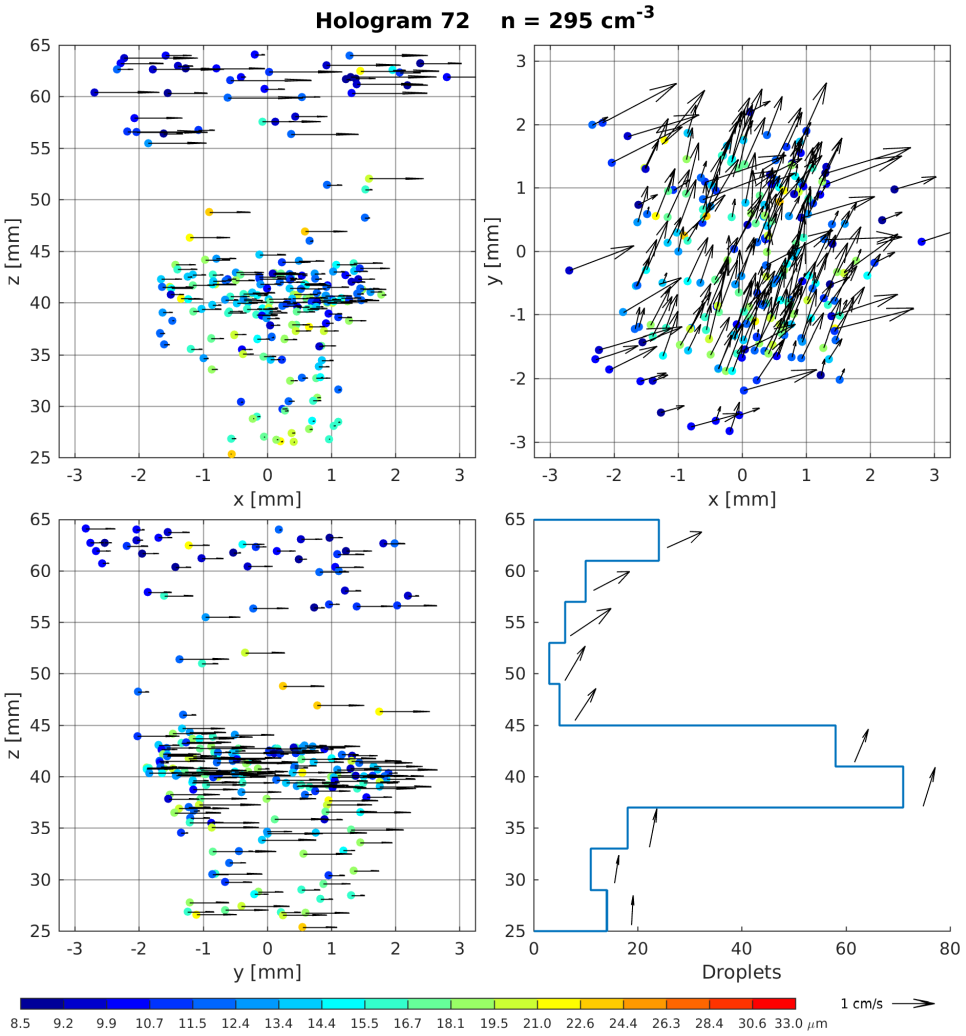

Figure 1: Droplets arrangement in a sample volume at one instance of time. Color scale denotes diameter while arrows horizontal velocity. (*top-left*),(*bottom-left*): projection of a scene onto vertical planes. (*top-right*): projection onto horizontal plane. (*bottom-right*): droplet number and average horizontal velocity in subsequent layers.

References

[1] W. W. Grabowski i L.-P. Wang, *Growth of Cloud Droplets in a Turbulent Environment*, Annual Review of Fluid Mechanics 45, pp. 293–324 (2013).

[2] K. E. Haman, S. P. Malinowski, M. J. Kurowski, H. Gerber, i J.-L. Brenguier, *Small scale mixing processes at the top of a marine stratocumulus - a case study*, Quarterly Journal of the Royal Meteorological Society 133, pp. 213–226 (2007).

[3] D. Gabor, *A New Microscopic Principle*, Nature 161, pp. 777–778 (1948).