Trajectories of Cloud Droplets around a Rain Drop Observed in Mainz Vertical Wind Tunnel

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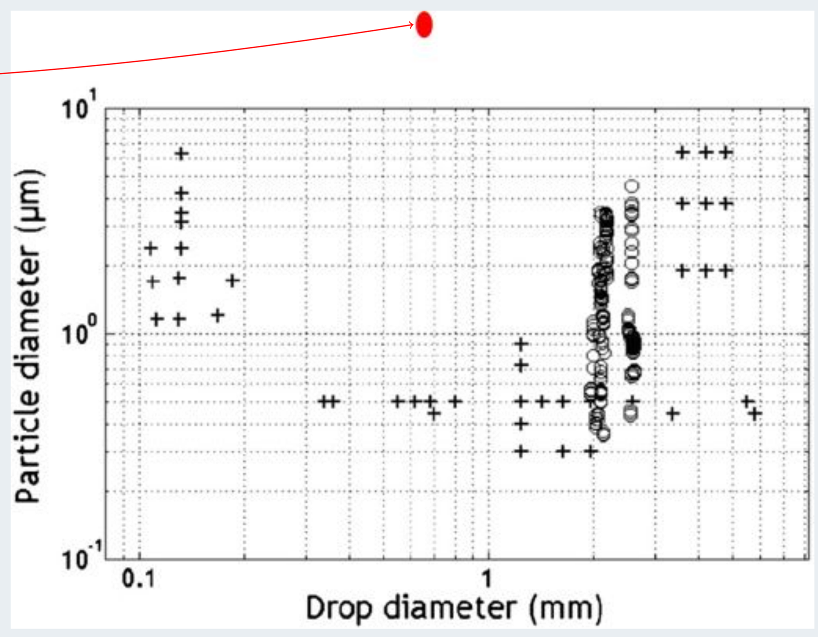
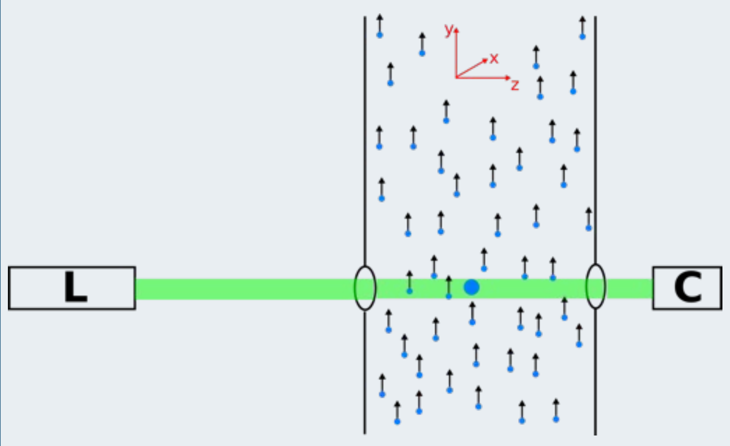
Introduction

Collisions are a crucial phenomena to understand aerosol scavenging by rain (Querel et al., 2014) and precipitation formation (Vohl et al., 2007), especially in certain regimes of collisions between cloud droplets themselves and between small rain drops and cloud droplets where there is a lack of data. Our experiment investigates collisions and near–collisions of cloud droplets with a rain drop by means of in–line holography. Measurements are performed in the Mainz vertical wind tunnel in a laminar flow. We present details of the experimental setup, data processing procedure, as well as first results of selected droplet trajectories.



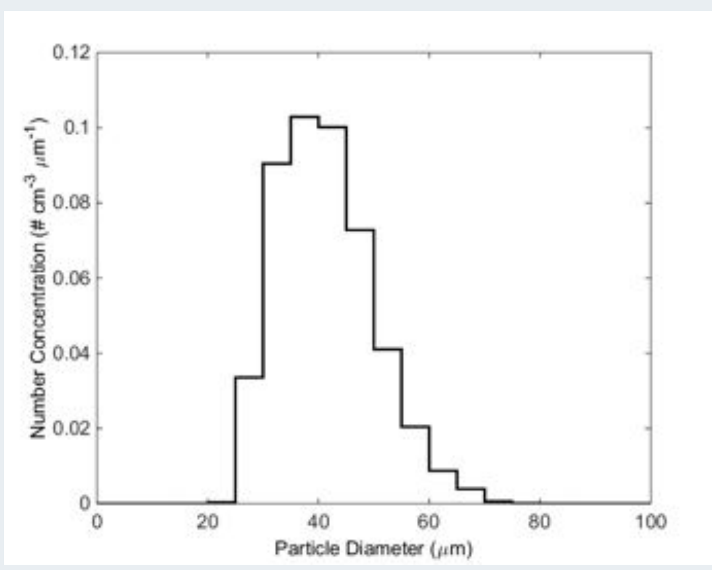
Experimental setup



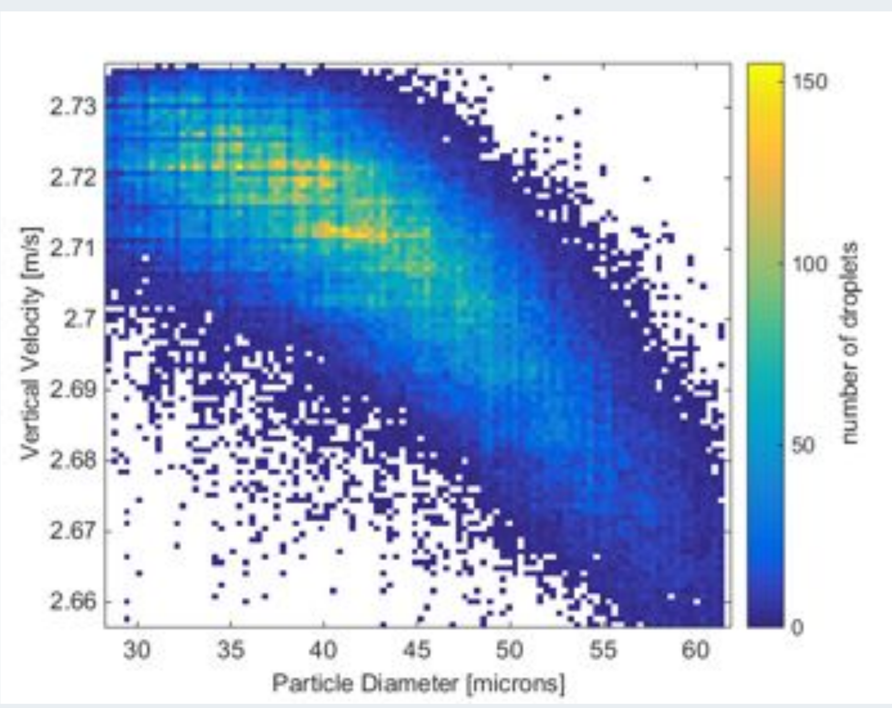
- L – laser
  - wavelength: 532 nm
  - frequency: 1040 Hz
- C – camera
  - resolution: 1280 × 1024 px
  - frame rate: 1040 fps
  - pixel size: 9.15 μm
- measurement section
  - sample volume dimensions: (x, y, z) = (9, 180, 12) mm
  - sample volume: 20 cm^3

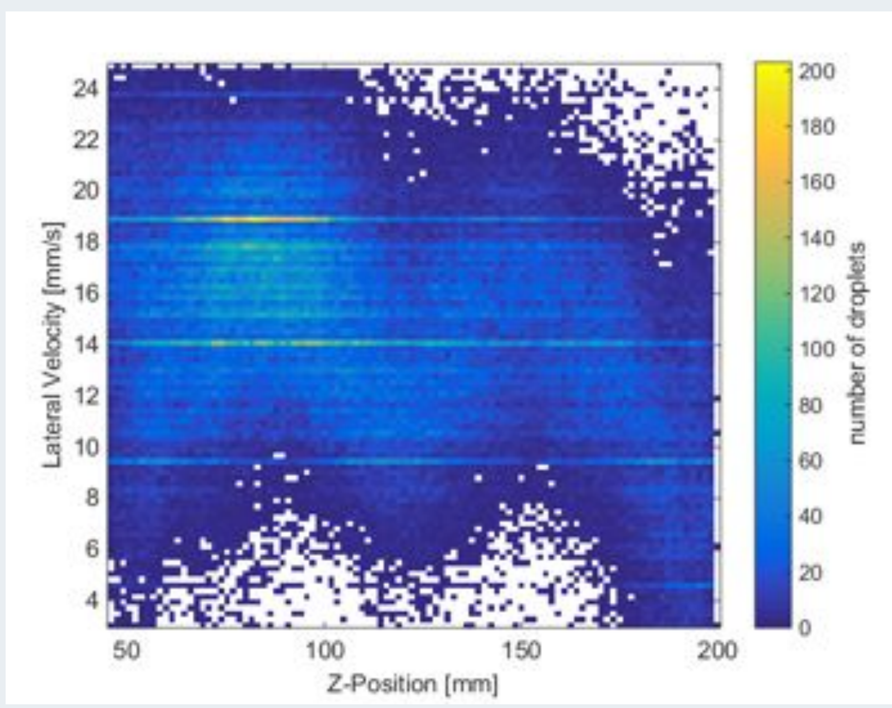
Flow parameters

- Terminal velocity: ∼2.9 m/s
- Temperature: ∼21.7℃
- Density: 2 droplets/cm^3
- Relative velocity between droplets and collector drop: 2.7 m/s
- Collector drop diameter: ∼675 μm
- Droplets diameters: 20–70 μm
- **4 to 5 point particle trajectories**
- **∼2 collisions per second**
- ∼5.5 seconds of data (5500 holograms)



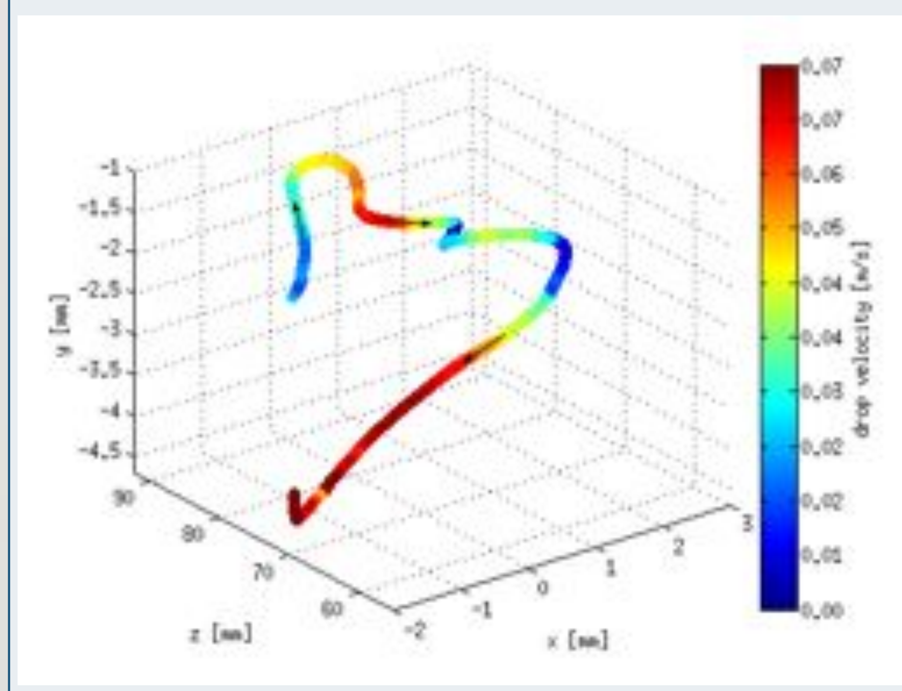
Flow structures

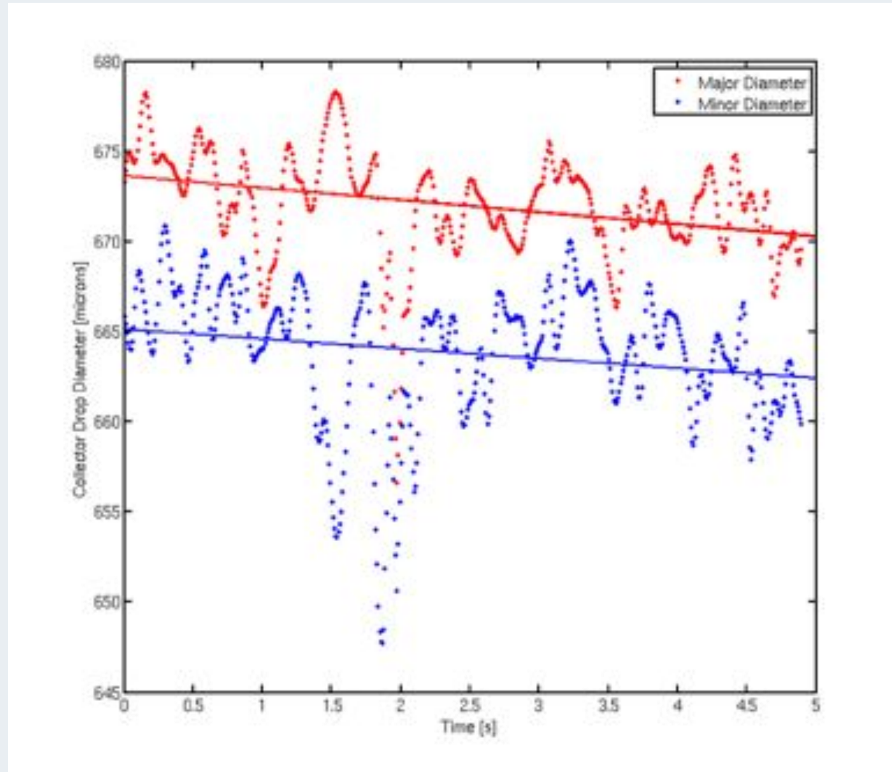




- Particle size is unbiased and uniform with position in the flow.
- Vertical velocity is laterally uniform in the sample volume.
- Droplet size has a strong correlation with its vertical velocity showing the expected dependence of sedimentation velocity on droplet size (left figure).
- Lateral velocity shows weak correlation with the lateral position (right figure).

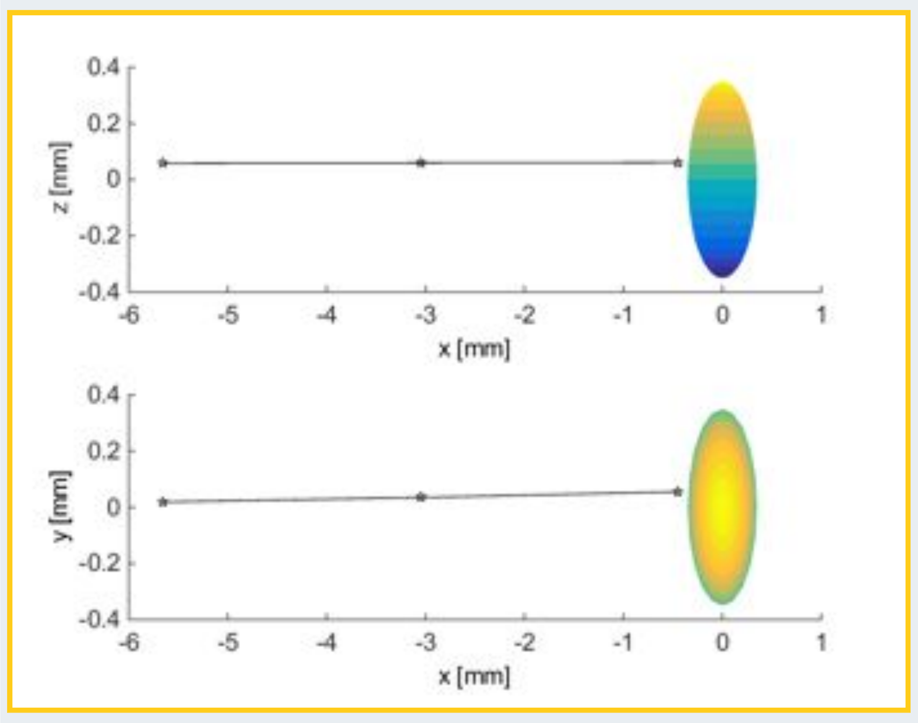
Rain drop trajectory and sizes

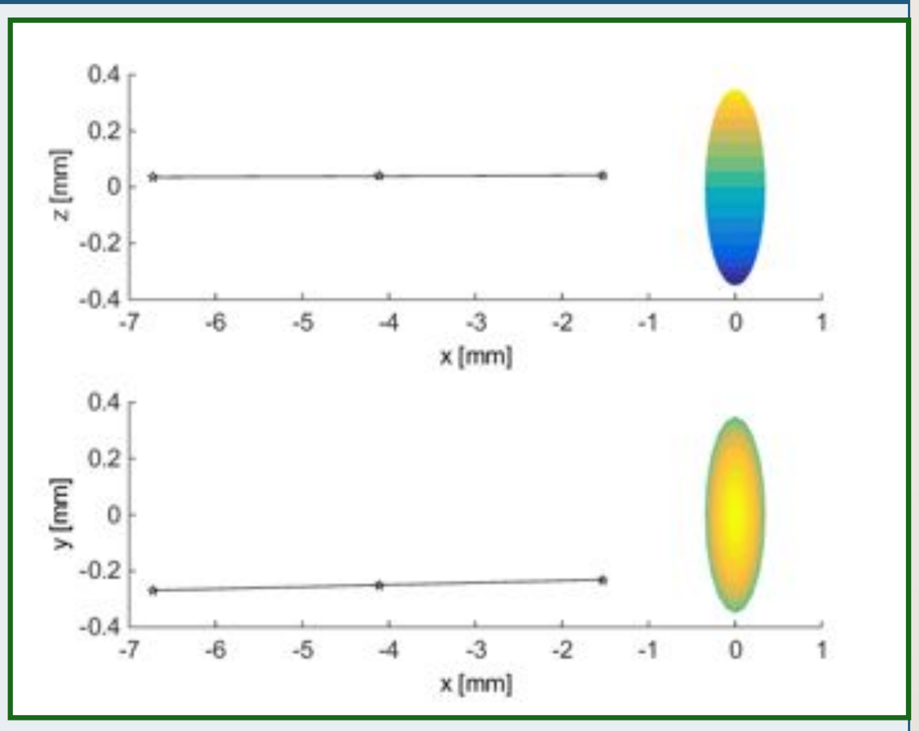




- Filtered rain drop trajectory showing also the drop velocity by color.
- Rain drop size also shrinks in time, about 10 μm (1 pixel) in 5 seconds. In this case, evaporation is stronger than growth by collision-coalescence.
- Also the minor diameter of a fitted ellipse about the rain drop is rather consistently one pixel or ∼10 microns smaller than the major diameter perhaps due to droplet asphericity due to its fall (Szakall et al., 2010).

Collisions





Collision	Time [ms]	Droplet size [μm]
1	621	35
2	1084	33
3	2004	40
4	2125	49
5	2229	33
6	2250	39
7	4164	60
8	4304	44

Conclusions

- Proof of concept that we can observe trajectories of collisions and near–collisions of cloud droplets with rain drops in the Mainz vertical wind tunnel.
- We found 8 collisions so far in 5.5 seconds of data.
- Drop and droplet size, impact parameter, flow characteristics (velocity field) are simultaneously measured.

Future work

- 45 seconds more of the same data set to analyze.
- Automate droplet injection.
- Further automate detection of collision and near–collisions.
- More measurements of different droplets and drops sizes.
- Higher–resolution and higher frame–rate camera to have better resolved tracks.

Acknowledgements

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References

A. Querel, M. Monier, A. I. Flossmann, P. Lemaitre, and E. Porcheron. The importance of new collection efficiency values including the effect of rear capture for the below–cloud scavenging of aerosol particles. Atmos. Res., 142:57–66, 2014. doi:10.1016/j.atmosres.2013.06.008.

M. Szakall, S. K. Mitra, K. Diehl, and S. Borrmann. Shapes and oscillations of falling raindrops – A review. Atmos. Res., 97:416–425, 2010.

O. Vohl, S. K. Mitra, S. Wurzler, K. Diehl, and H. R. Pruppacher. Collision efficiencies empirically determined from laboratory investigations of collisional growth of small raindrops in a laminar flow field. J. Atmos. Res., 85:120–125, 2007. doi:10.1016/j.atmosres.2006.12.001.

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