

Ejection of marine microplastics by raindrops. A computational and experimental study

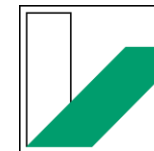
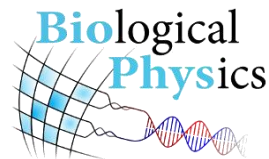
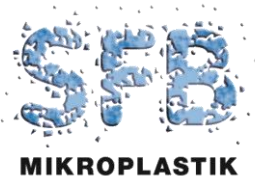
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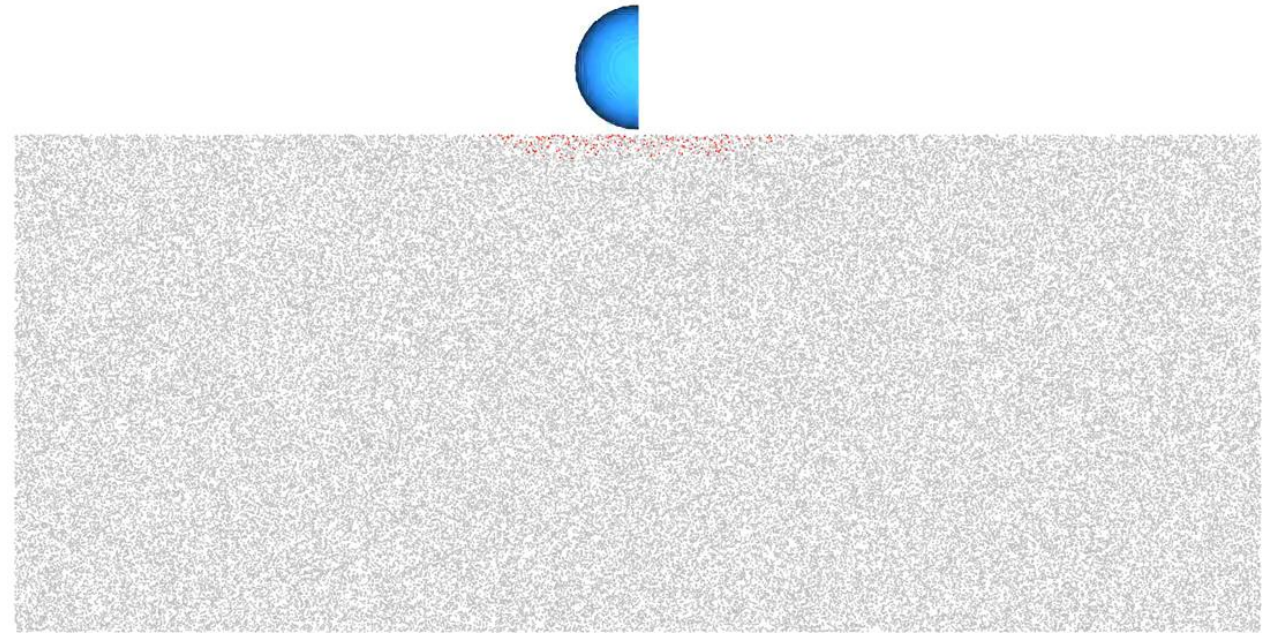
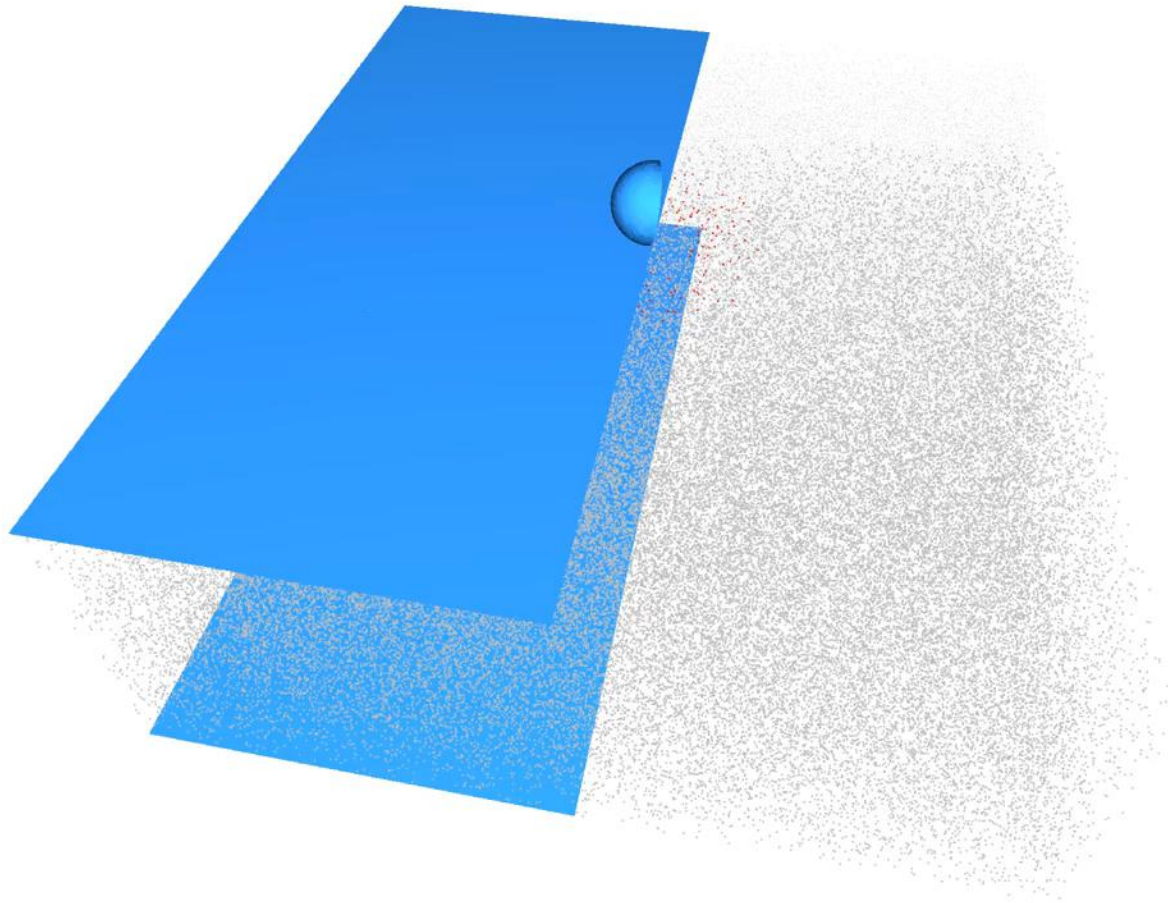
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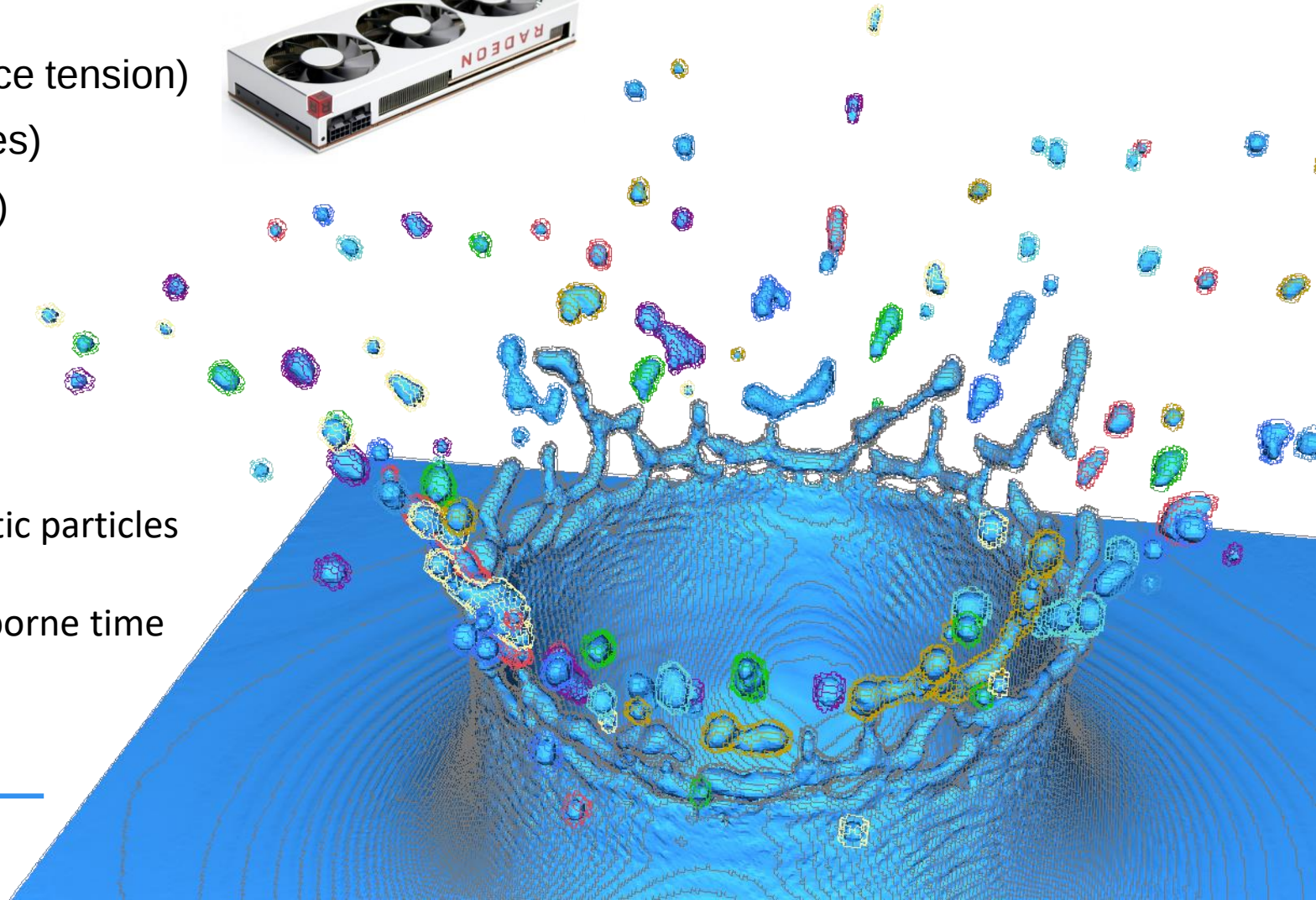


Simulating 4mm Raindrop Impact



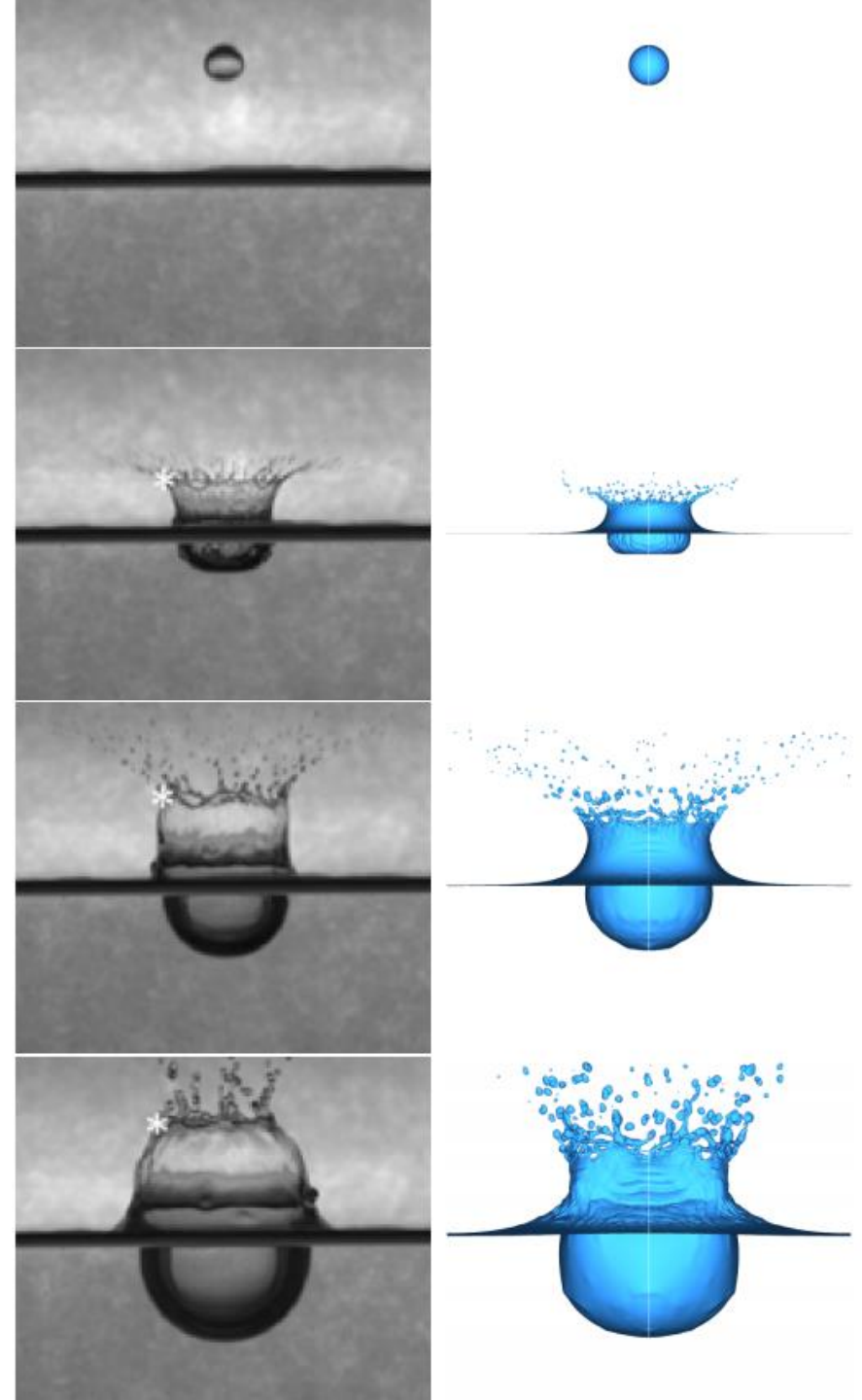
Numerical Methods – FluidX3D CFD Software

- lattice Boltzmann method (fluid flow)
- volume-of-fluid (water surface, surface tension)
- immersed-boundary method (particles)
- Hoshen-Kopelman (droplet counting)
- > 1600 impact simulations on GPU
- output
 - primary: size / velocity / microplastic particles contained within of spray droplets
 - secondary: droplet trajectory / airborne time
 - particle origin



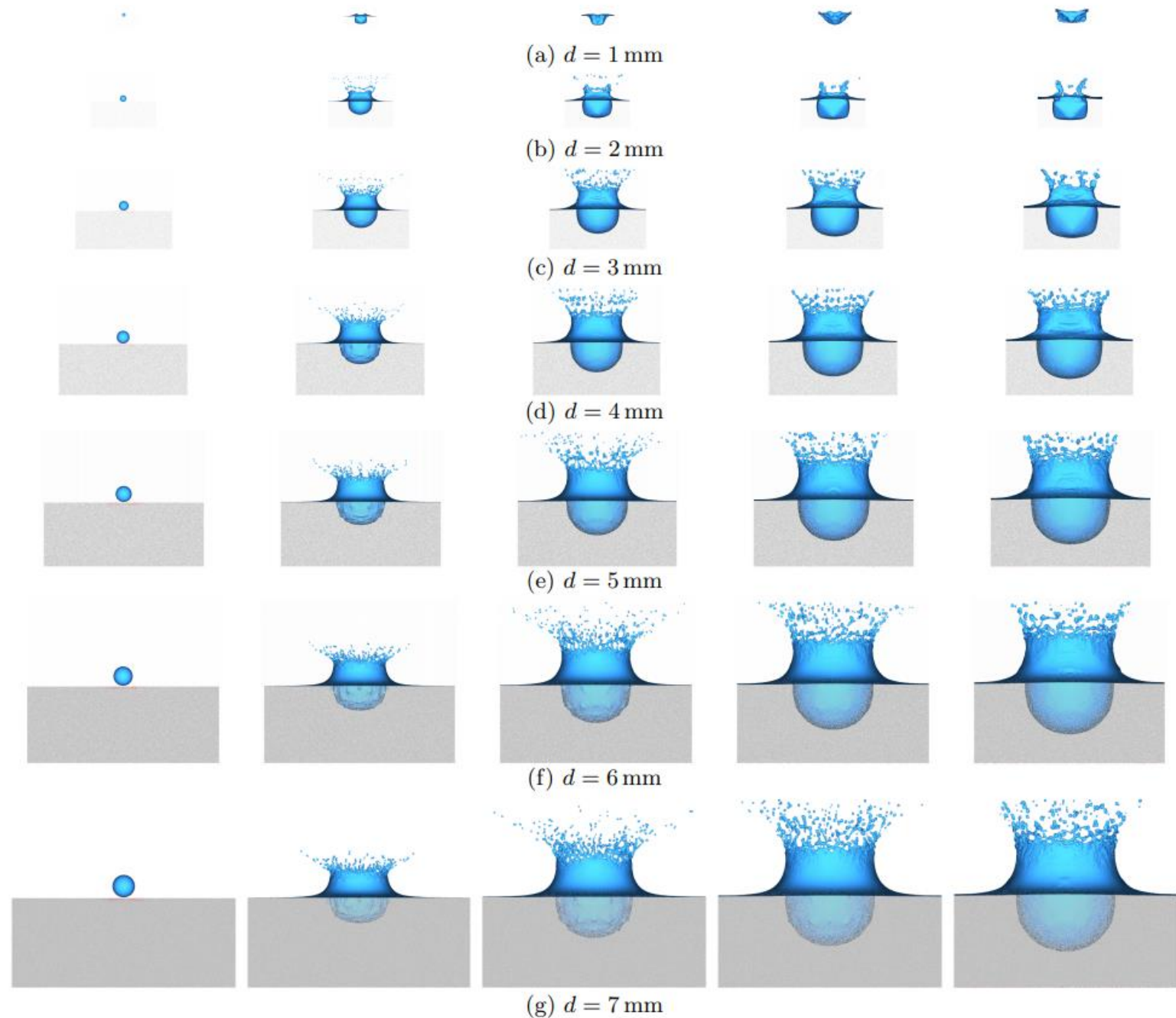
Validation

- 4.1 mm raindrop impact
- simulation parameters match experiment 1:1
- very good agreement during initial splash phase

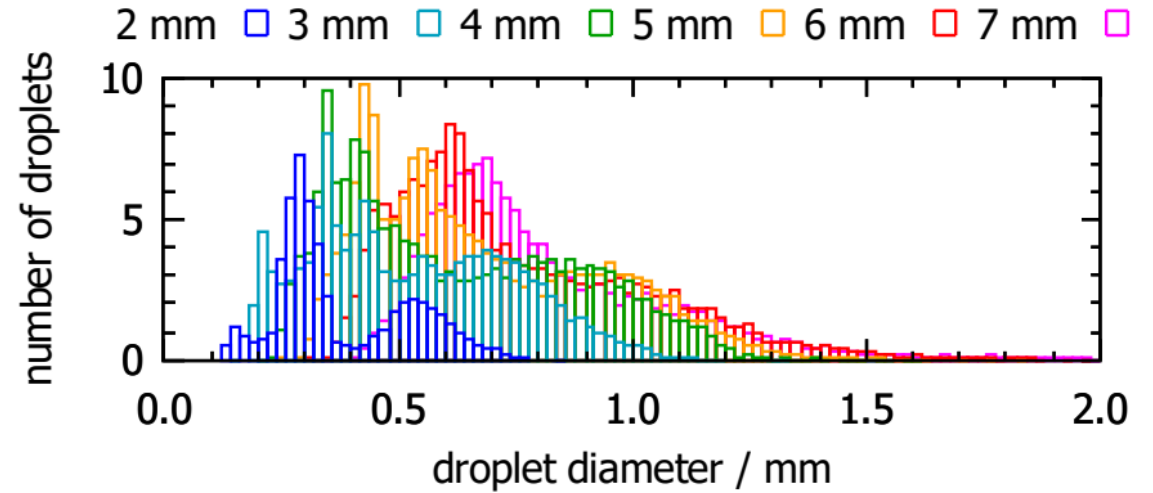


Different Raindrop Diameter

1mm – 7mm

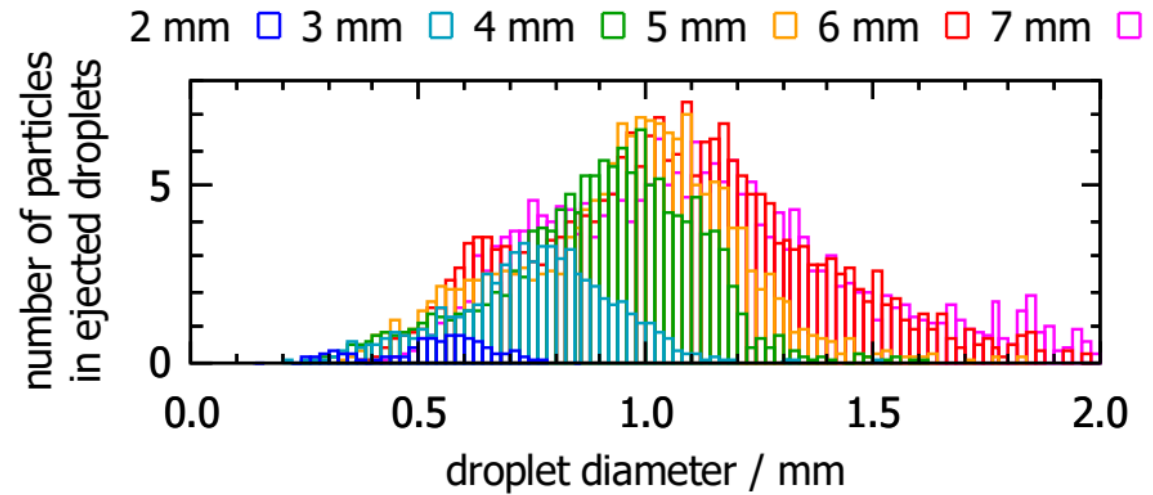


Spray size distribution:



(a)

Where are the particles?



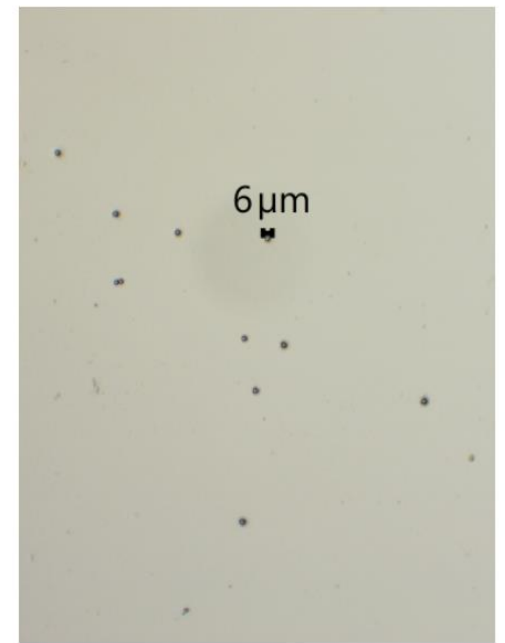
(b)

Experiments

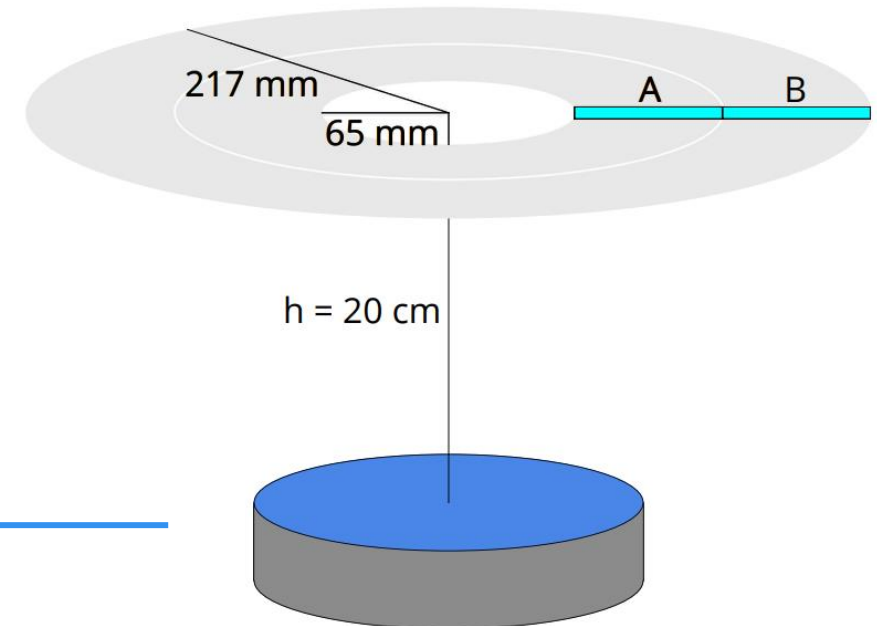
- impact drop in reservoir
- count droplets & particles on glass slide placed above reservoir
- good agreement with simulation
 - 1.3x more droplets
 - 2.5x more particles
 - ... compared to simulation



(a)

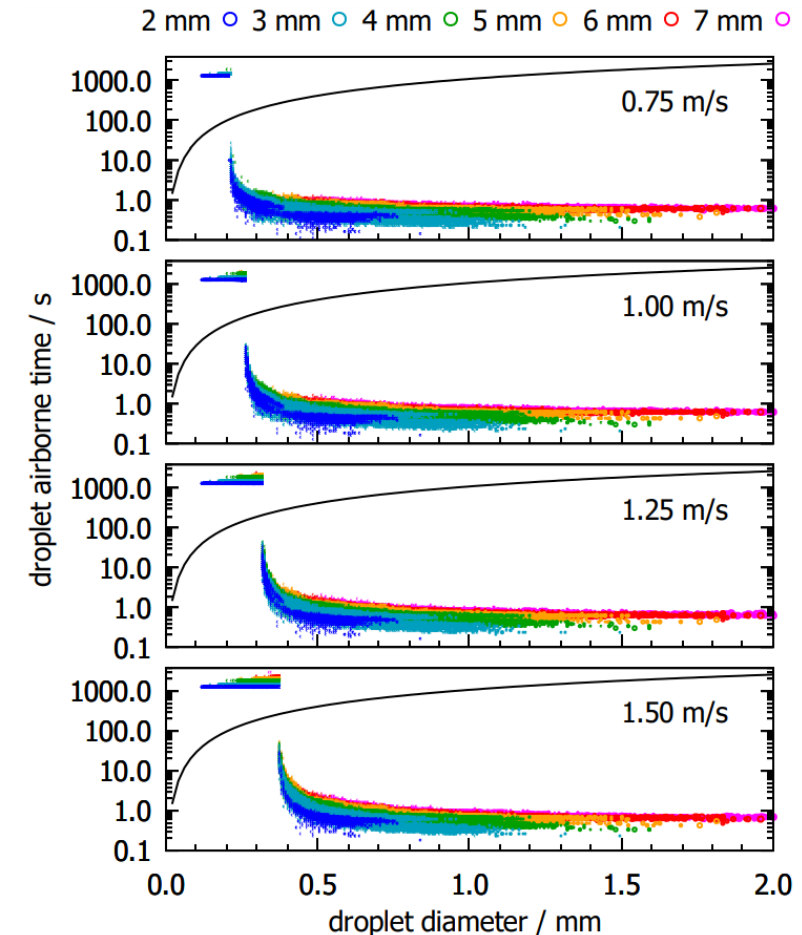
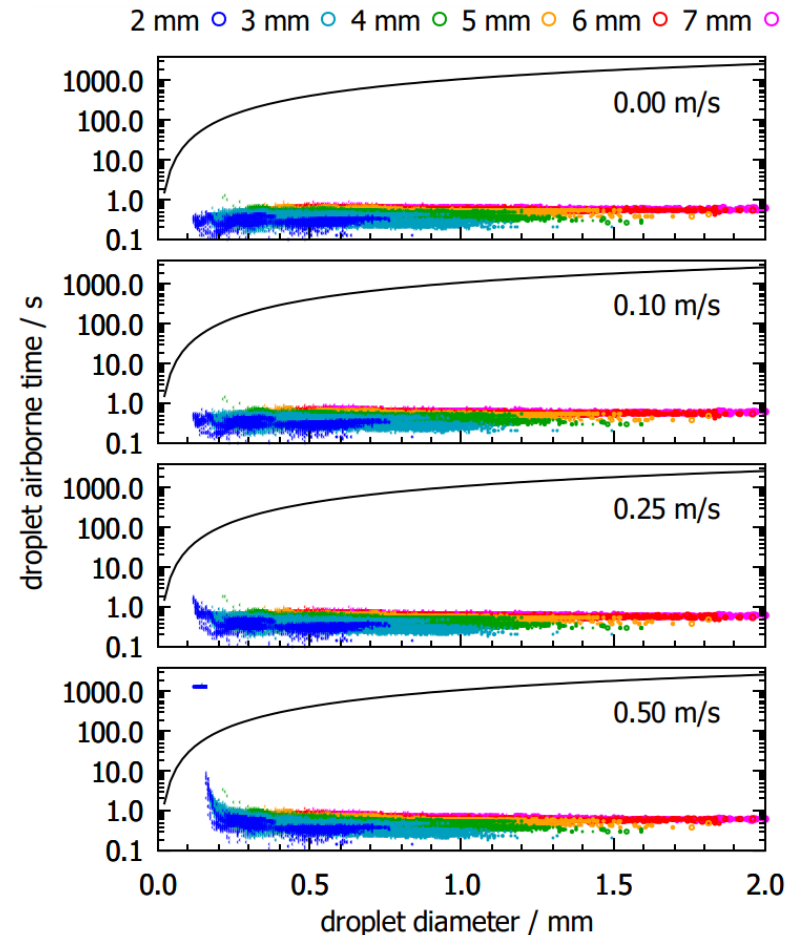


(b)



Droplet Airborne Time

- integrate droplet trajectories
- initial conditions (LBM)
+ drag model
+ evaporation in air
- look at airborne time for different vertical wind speed



Global Annual Estimate

- simulation results: transitioning particles per raindrop impact
- additional models + data
 - air friction on viscous droplet (Feng)
 - airborne droplet evaporation (Holterman)
 - updraft speed $< 0.75\text{m/s}$ (Ouwersloot)
 - 2.9 particles/L at ocean surface (Pabortsava)
 - raindrop size distribution (Marshall-Palmer)
 - rain rate distribution (Rice-Holmberg)
- $< 10^{14}$ particles transition per year globally
- large uncertainties: variation in ocean microplastic concentration, many model simplifications

