High-Fidelity Simulations of Water Jet in Air Crossflow

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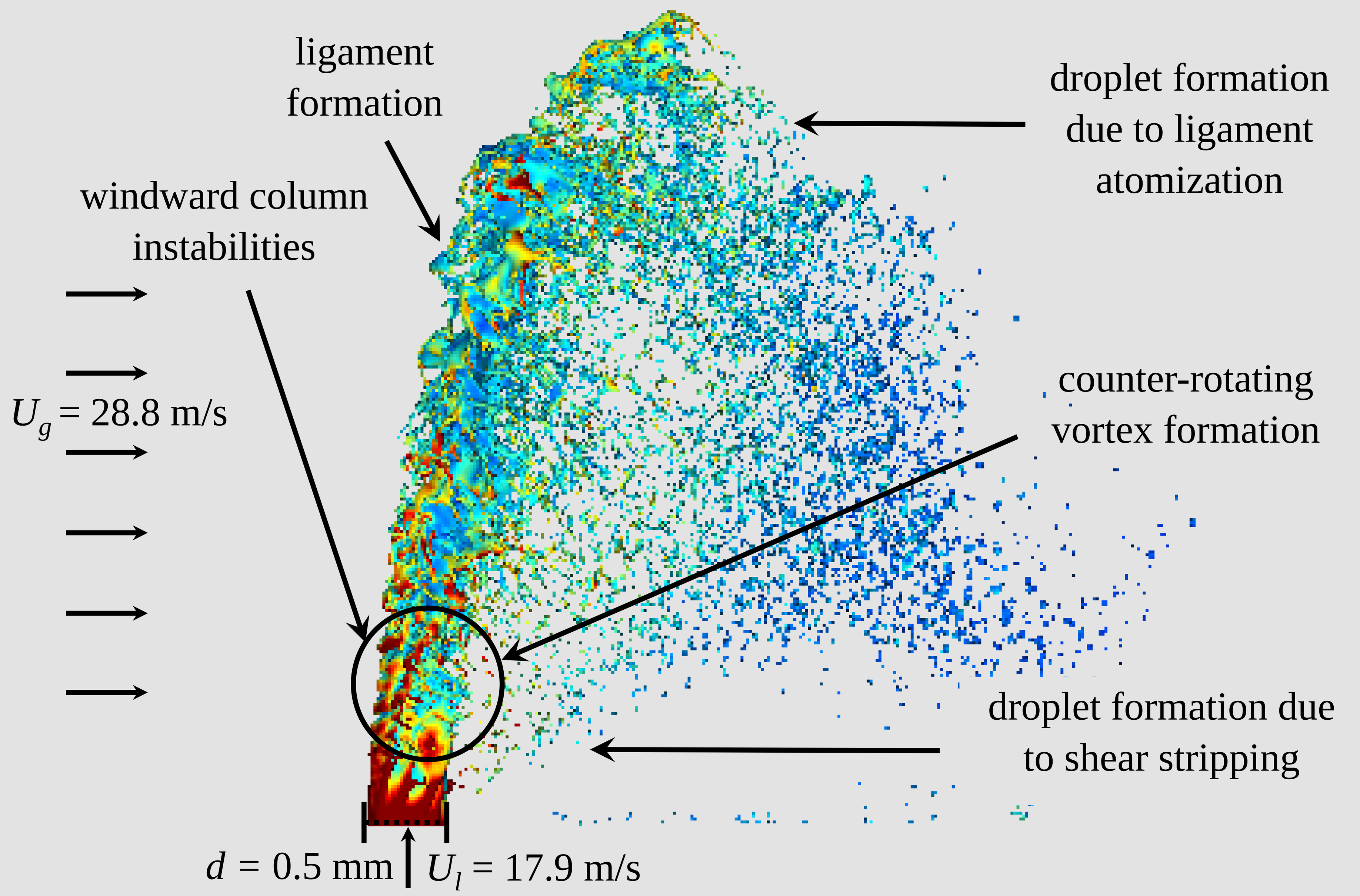
Phenomenon Investigated



Objectives

- Investigate detailed physics underlying liquid jets in crossflow configurations applicable to various applications such as, gas-turbine, scramjet, and afterburner fuel injection.
- Develop models to predict the statistical behaviors of resulting droplets.

Physical Parameters and Operating Conditions

	P (bar)	T (K)	We	Momentum ratio, q
Operating Conditions	20	300	54.9	15.5

	σ (N/m)	ρ_l (kg/m^3)	μ_l (kg/m-s)
Water Properties	0.0729	1000	0.001

Methodology

Incompressible, variable-density, Navier-Stokes equations:

$$\rho(\partial_t \mathbf{u} + \mathbf{u}\cdot\nabla\mathbf{u}) = -\nabla p + \nabla\cdot(2\mu\mathbf{D}) + \sigma\kappa\delta_s\mathbf{n}$$
$$\partial_t \rho + \nabla\cdot(\rho\mathbf{u}) = 0$$
$$\nabla\cdot\mathbf{u} = 0$$

Volume fraction, two-phase fluid density and viscosity:

$$\rho(c) \equiv c\rho_1 + (1-c)\rho_2$$
$$\mu(c) \equiv c\mu_1 + (1-c)\mu_2$$

- Second-order piecewise-linear geometrical VOF scheme

Advection for volume fraction:

$$\partial_t c + \nabla\cdot(c\mathbf{u}) = 0$$

Relevant Non-Dimensional Numbers

$$We = \frac{\rho_g U_l^2 d}{\sigma}$$

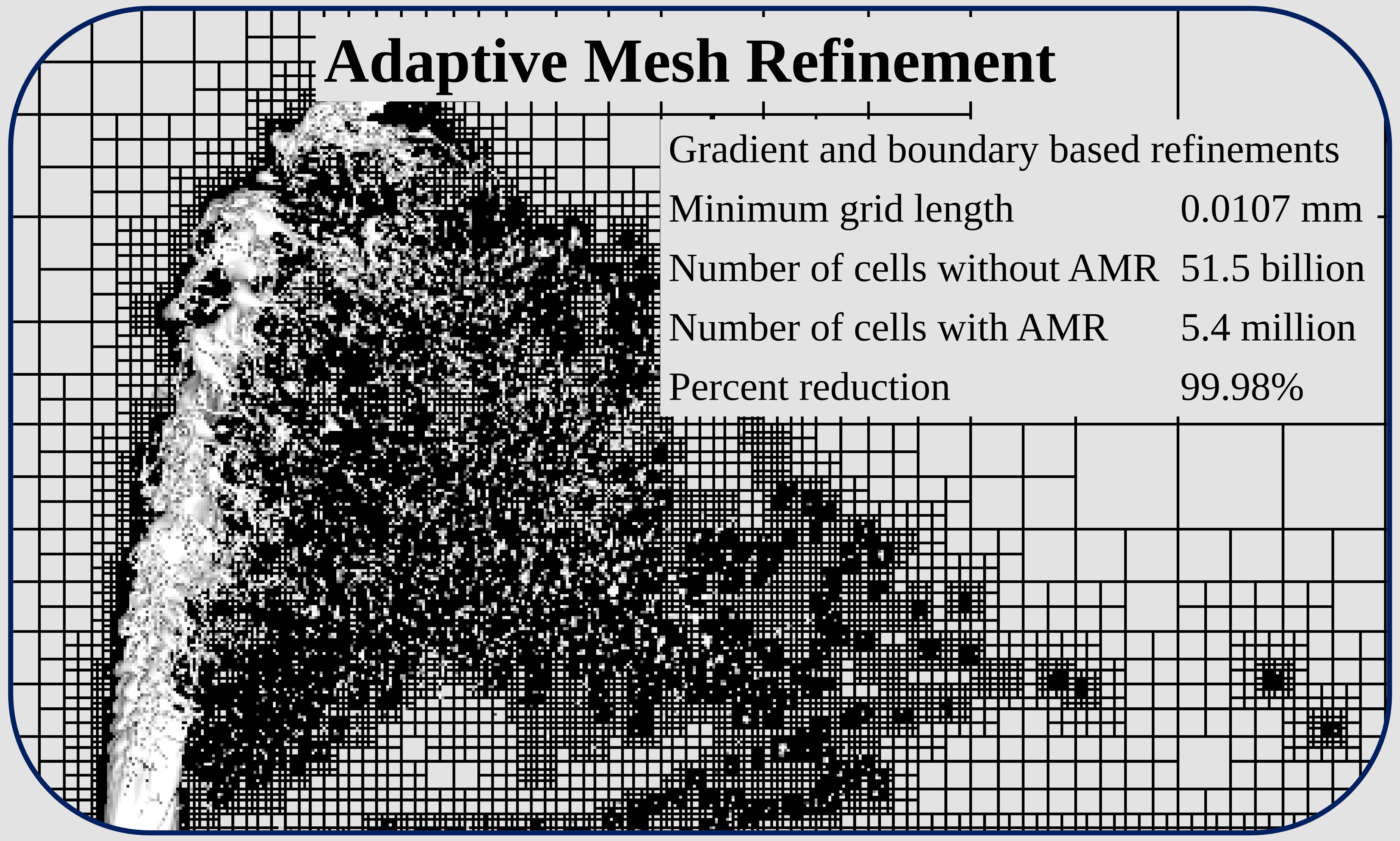
$$q = \frac{\rho_l U_l^2}{\rho_g U_g^2}$$

Validation

Penetration at x/d = 14.16

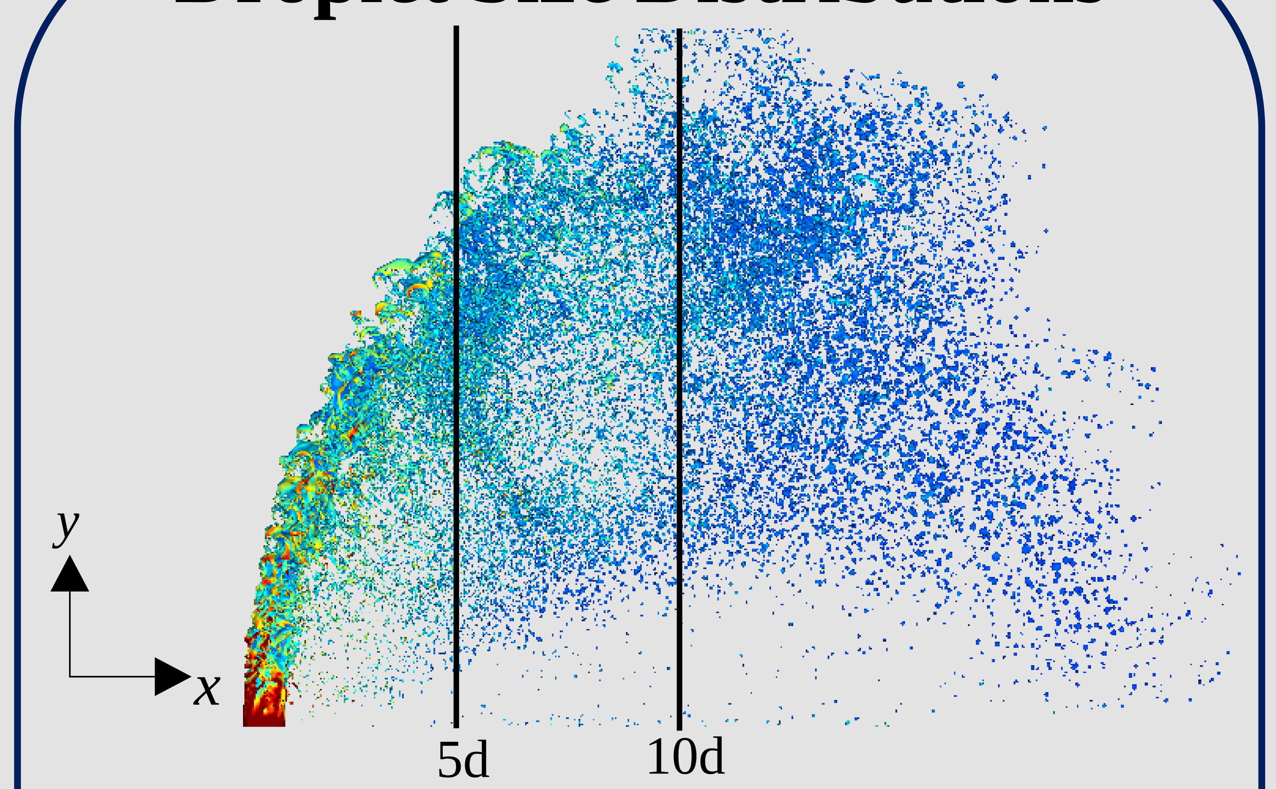
	Experiment (Ragucci et al., 2007)	Present	% Error
y/d	19.88	18.14	8.72

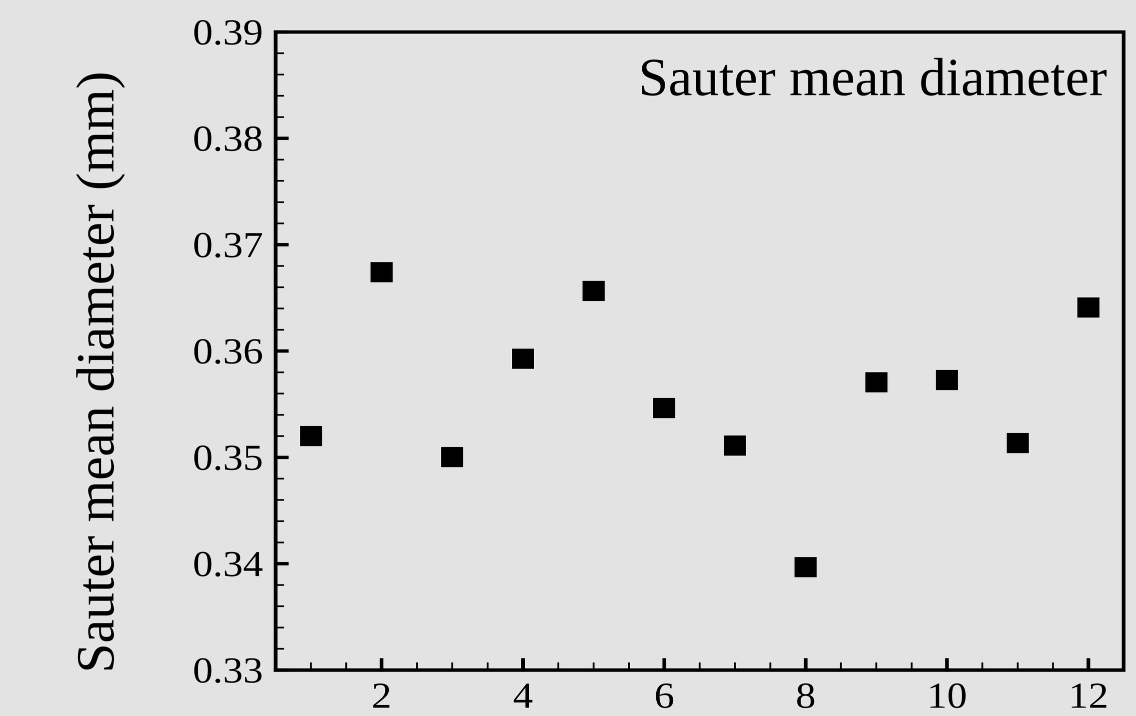
Adaptive Mesh Refinement

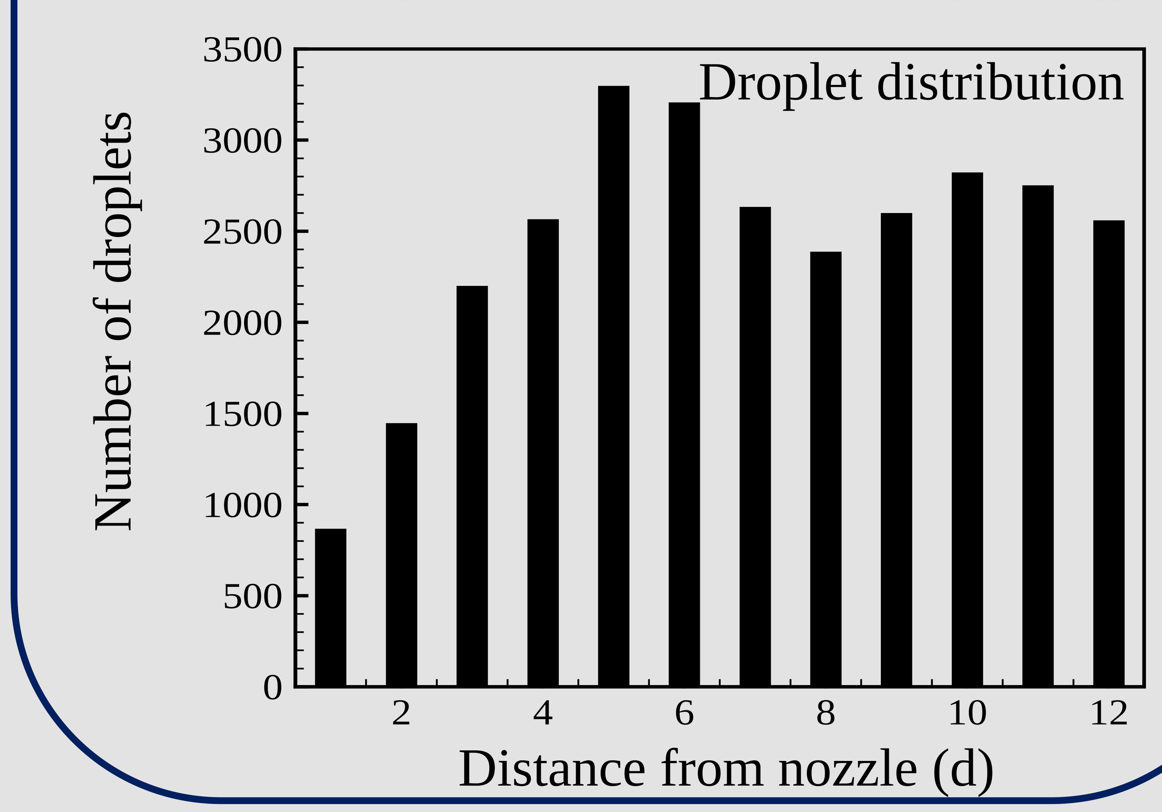


Gradient and boundary based refinements	
Minimum grid length	0.0107 mm
Number of cells without AMR	51.5 billion
Number of cells with AMR	5.4 million
Percent reduction	99.98%

Droplet Size Distributions







Detailed Physics of Liquid Jet in Crossflow

Liquid Iso-Surface Colored by Vorticity Magnitude

non-dimensional time, t = t*/(d/U_j)