Understanding particle-induced mixing in particle-laden turbulent flows

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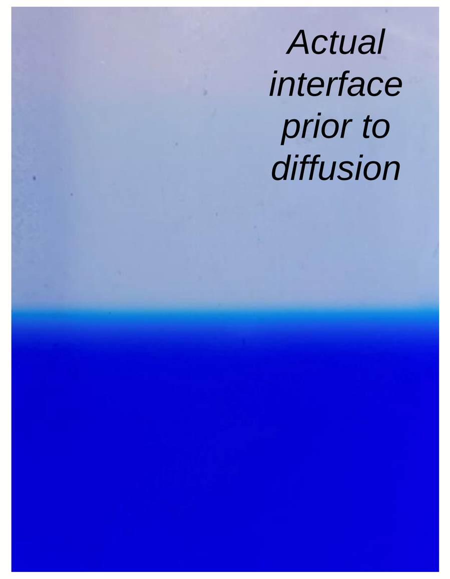
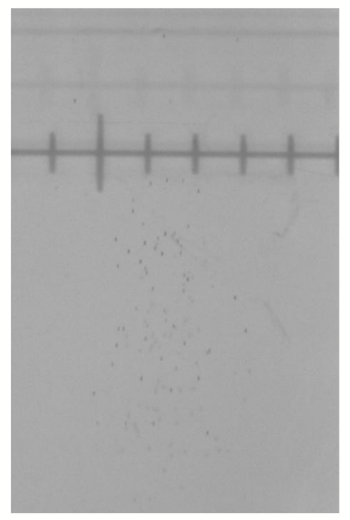
Background & Objectives

- Experiments are in progress to study interaction between a particle and a fluid interface, focusing on the dependence of mixing on Re_p and $\frac{\rho_p}{\rho_f}$, but they do not capture the velocity field.
- The objective is to use particle-resolved direct numerical simulations (PR-DNS) to replicate the setup and gather detailed flow field data.



Falling particles in an empty tank



Computational Methods

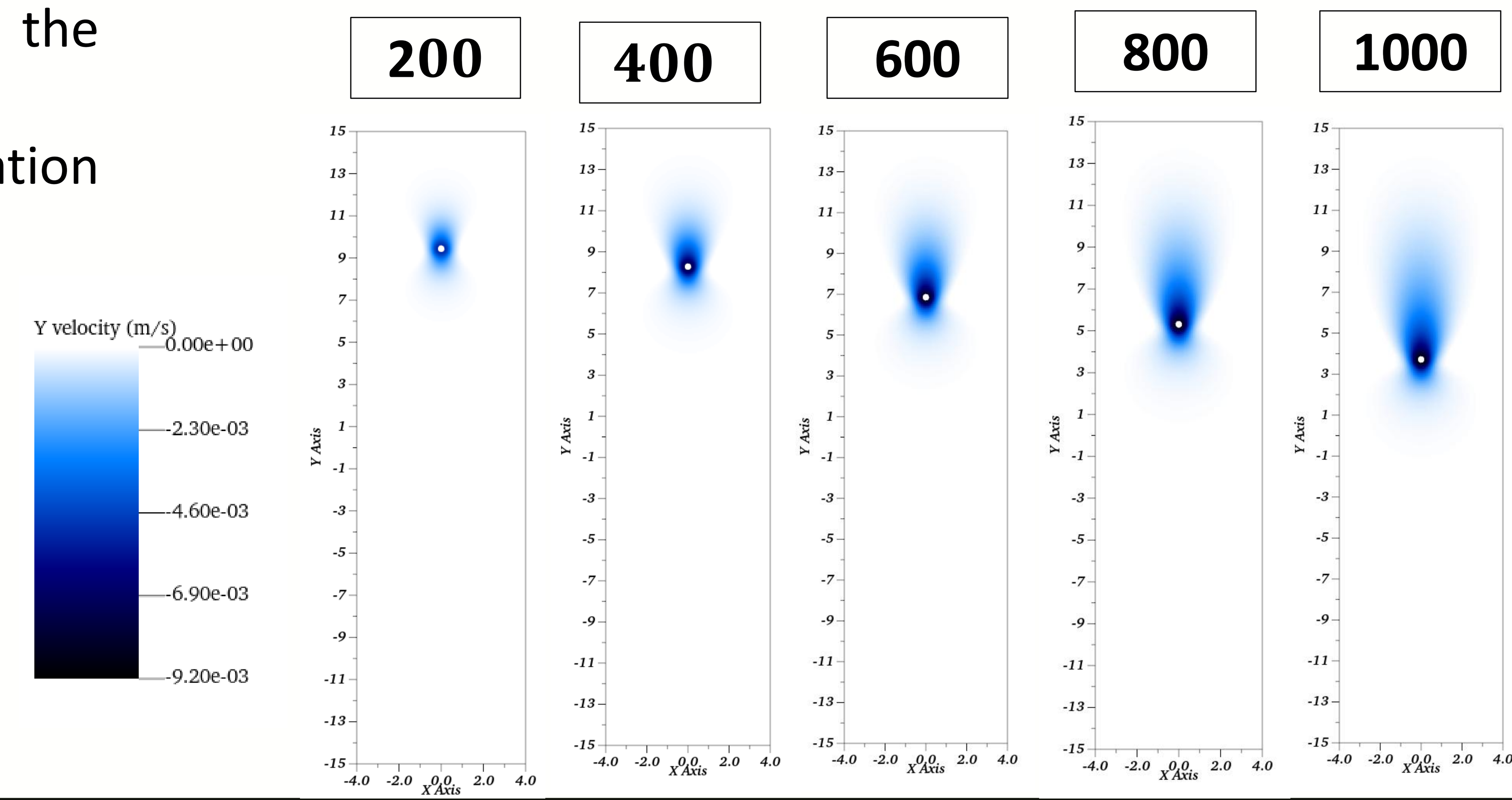
- Simulations were run using LEAP solver to achieve the target Reynolds numbers as listed in the tables below.
- The Galileo number is used to derive simulation parameters from experimental data.

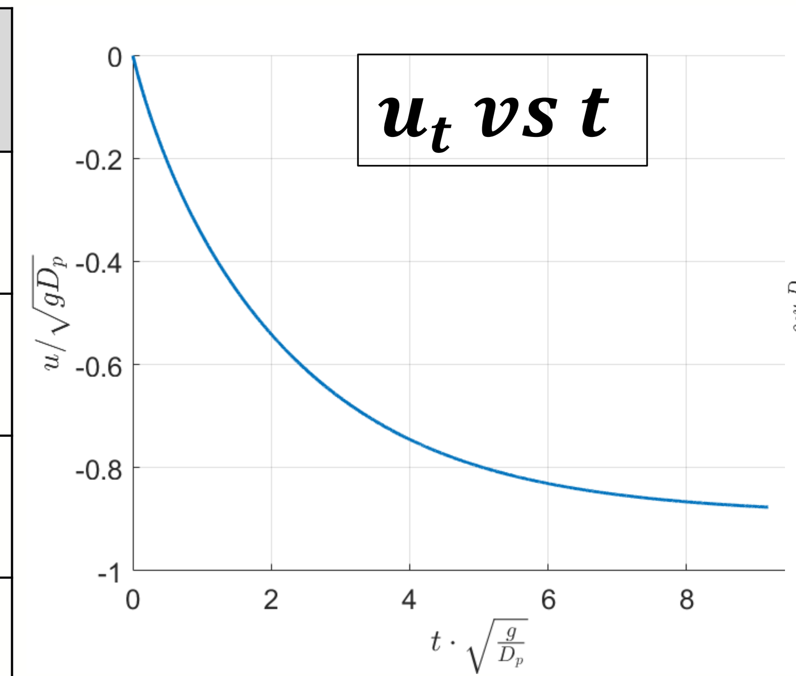
$Non-Dimensional\ Parameters$		
$Density\ Ratio$	$\frac{\rho_p}{\rho_f}$	4.404
$Particle\ Reynolds\ Number$	$Re_p = \frac{\rho_f d_p v_p}{\mu_f}$	9.162
$Galileo\ Number$	$Ga = \sqrt{\frac{\left(\frac{\rho_p}{\rho_f} - 1\right) g D_p^3}{\nu^2}}$	16.94

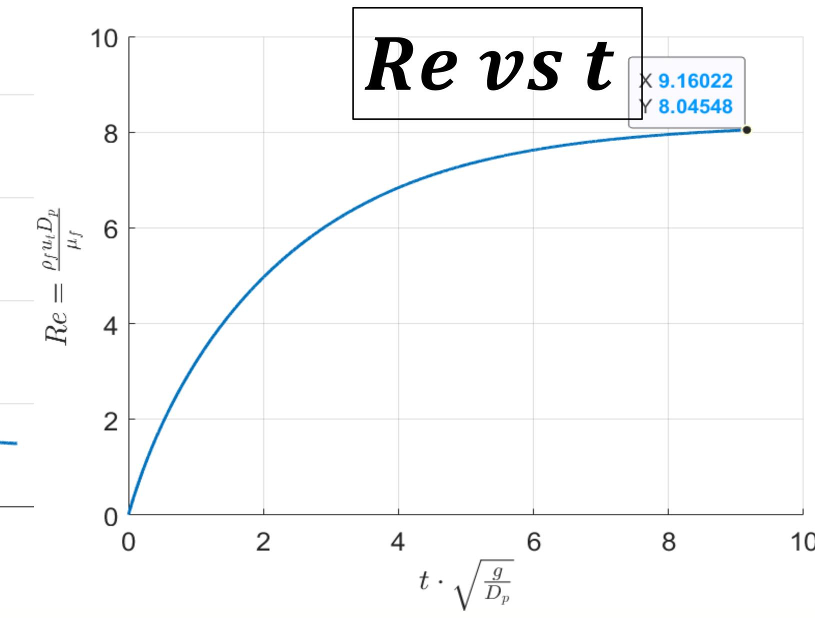
$Physical\ Parameters$	$Symbols$	$Experimental\ parameters$	$Simulation\ parameters$
$Particle\ Density\ (\frac{kg}{m^3})$	ρ_p	4500	4.404
$Particle\ Diameter\ (m)$	d_p	228×10^{-6}	1
$Particle\ Terminal\ Velocity\ (\frac{m}{s})$	v_p	0.0472	–
$Fluid\ Density(\frac{kg}{m^3})$	ρ_f	1021.7	1
$Fluid\ Viscosity(Pa.s)$	μ_f	0.0012	1×10^{-3}
$Acceleration\ Due\ to\ Gravity(\frac{m}{s^2})$	g	9.81	8.43×10^{-5}

- Domain size is $8\,m \times 30\,m \times 8$ m, with a grid resolution $\Delta x = 0.0833$ & $96 \times 360 \times 96$ grid points. The time step is $0.02\ seconds$, & total simulation is run for $1000\ seconds$.

Results & Discussion







- Terminal velocity, $v_p = 0.800\sqrt{gD_p}$ and Terminal Re_p of 8.045 is reached.
- More iterations required reach $Re_p = 9$.
- Current approach gives a physical consistent carrier flow field and particle motion to simulate the mixing using the advection diffusion equation.

Future Work

- We solve the advection–diffusion equation for concentration for an array of particles.
- Based on these, we estimate the effective mass diffusivity and compare the experimental findings.

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