Dynamics of Droplets in Turbulence

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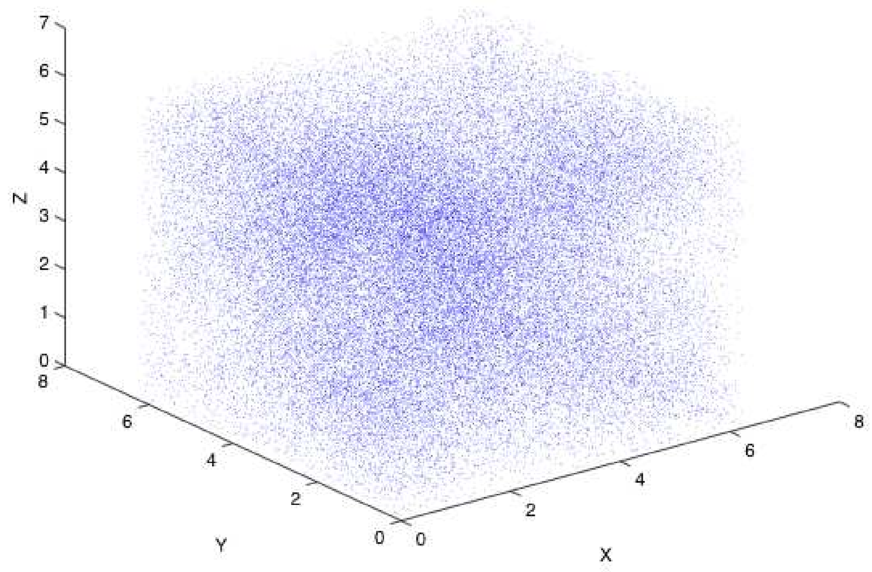
Motivation:

- Mathematical and computational study of the motion of small droplets in a turbulent flow under the effect of temperature gradients.
- Evaporation and condensation of droplets; collisions and coalescence.
- Application: Particle removal efficiency for cleansing of exhaust gases.



Particles moving in turbulence

Fluid flow model:

- Navier-Stokes: The turbulent velocity field $\mathbf{u}$ = (u,v,w) is governed by incompressible NS equation

$$\frac{\partial \mathbf{u}}{\partial t} + (\mathbf{u}\cdot\bigtriangledown)\mathbf{u} = -\bigtriangledown p + \nu \bigtriangledown^2 \mathbf{u} + \mathbf{F} \qquad (1)$$
$$\bigtriangledown . \, \mathbf{u} = 0$$

  where **F** is the forcing term.
- Fluid temperature equation: It is modeled as a passive scalar in the flow field by the advection-diffusion equation

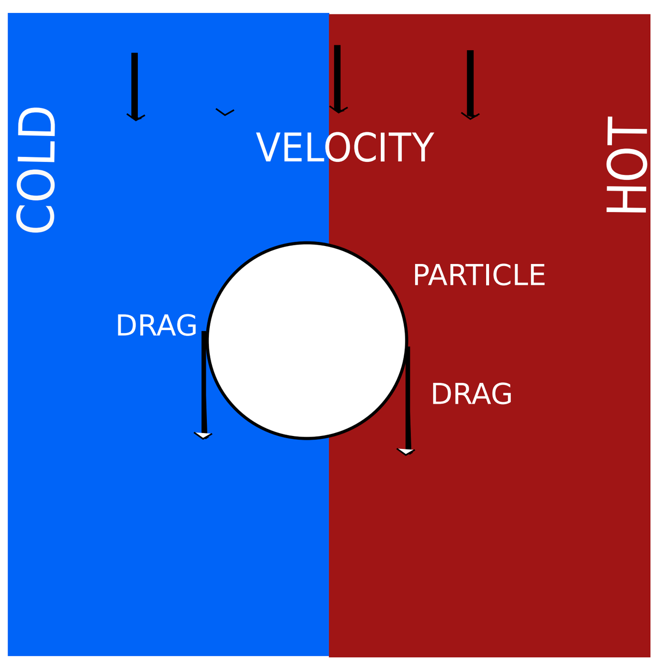
$$\frac{\partial \mathrm{T}}{\partial t} + (\mathbf{u}\cdot\nabla)\mathrm{T} = \kappa \nabla^2 \mathrm{T} \qquad (2)$$

  where κ is the diffusion constant.
- Numerical scheme: We use a pseudó-spectral method for DNS of the turbulent flow field.

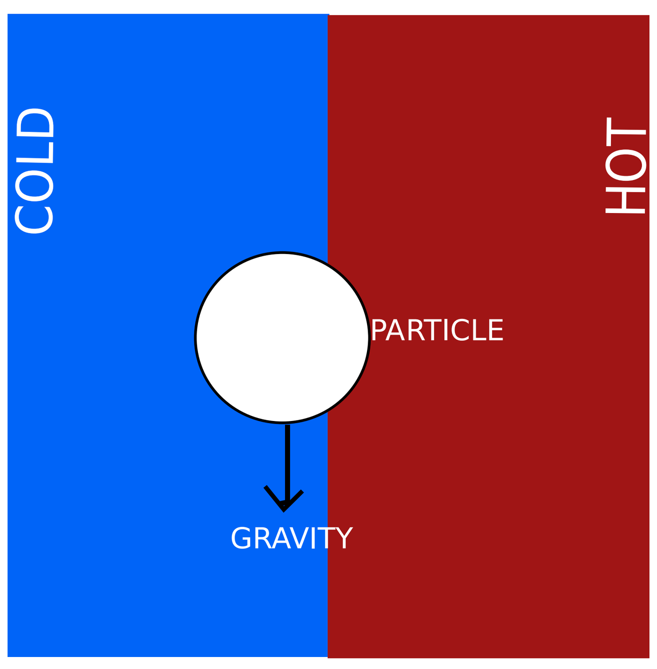
Forces on a droplet:

The dominant forces which affect the trajectory of a droplet in the flow domain are;

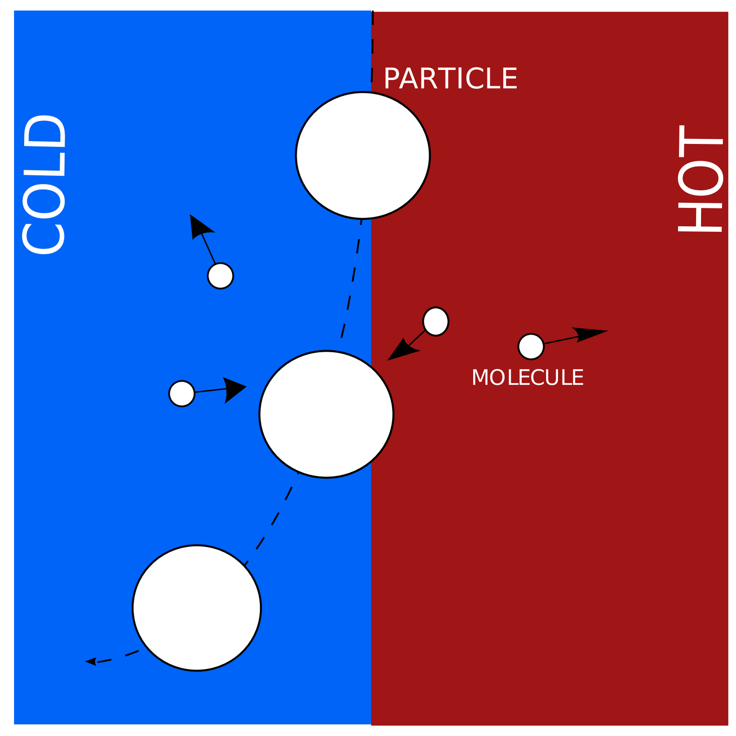
- **Stokes drag**: Resistance to the relative motion in the flow field.



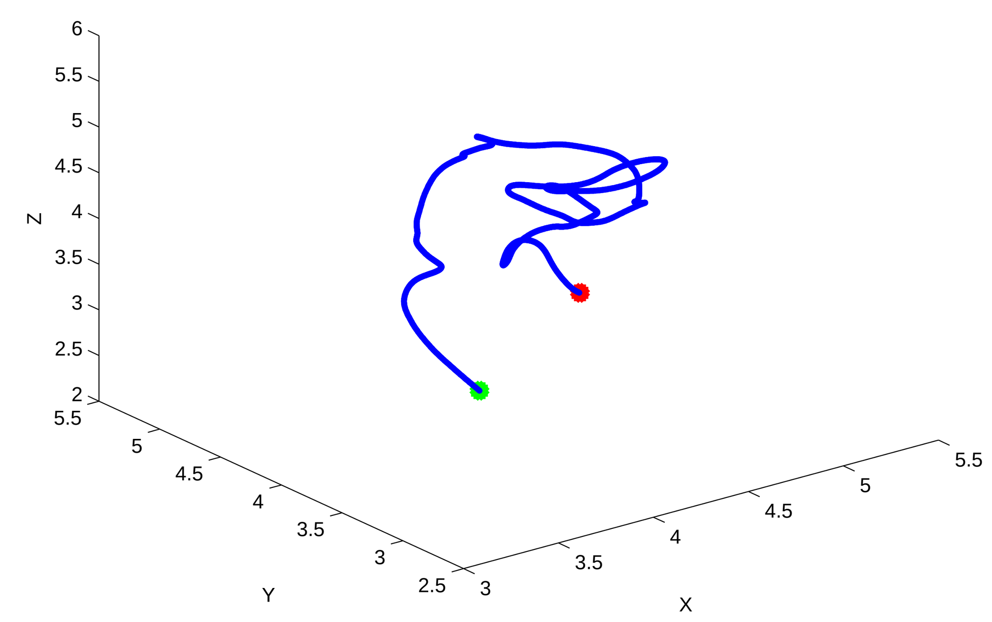
- **Gravity**: Force due to gravitational attraction.



- **Thermophoresis**: Motion of the particles towards colder region of the domain under the effect of a temperature gradient.



Governing equation for droplets:



Trajectory of a particle under Stokes drag

We neglect collision and coalescence among the droplets. The equations governing the droplet motion becomes,

$$\frac{\mathrm{d}\mathbf{v}}{\mathrm{dt}} = \underbrace{\frac{\mathbf{u}-\mathbf{v}}{\tau}}_{\mathrm{I}} + \underbrace{\mathbf{G}}_{\mathrm{II}} + \underbrace{\frac{-9\pi H}{2}\frac{\mu^2 R}{\rho m_p}\left(\frac{\bigtriangledown \mathrm{T}}{\mathrm{T}_0}\right)}_{\mathrm{III}} \qquad (3)$$

$$\frac{\mathrm{dT}_0}{\mathrm{dt}} = \frac{Nu}{2}\,\frac{\mathrm{T}_0 - \mathrm{T}}{\tau_T} \qquad (4)$$

$$\frac{\mathrm{d}\mathbf{x}}{\mathrm{dt}} = \mathbf{v} \qquad (5)$$

- I : Stokes Drag.
- II : Gravity.
- III : Thermophoresis.

Dynamic coupling:

- Particle motion and temperature determined by Stokes response time τ and τ_T.
- Size of particle determines τ and τ_T.
- The droplets will explore region with different thermodynamic properties: phase transition. Evaporation and condensation couple particle motion to particle thermodynamic properties.

Outlook:

- Size distribution of particles due to evaporation and condensation.
- Thermophoresis is studied in the deposition phenomenon near a wall.

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