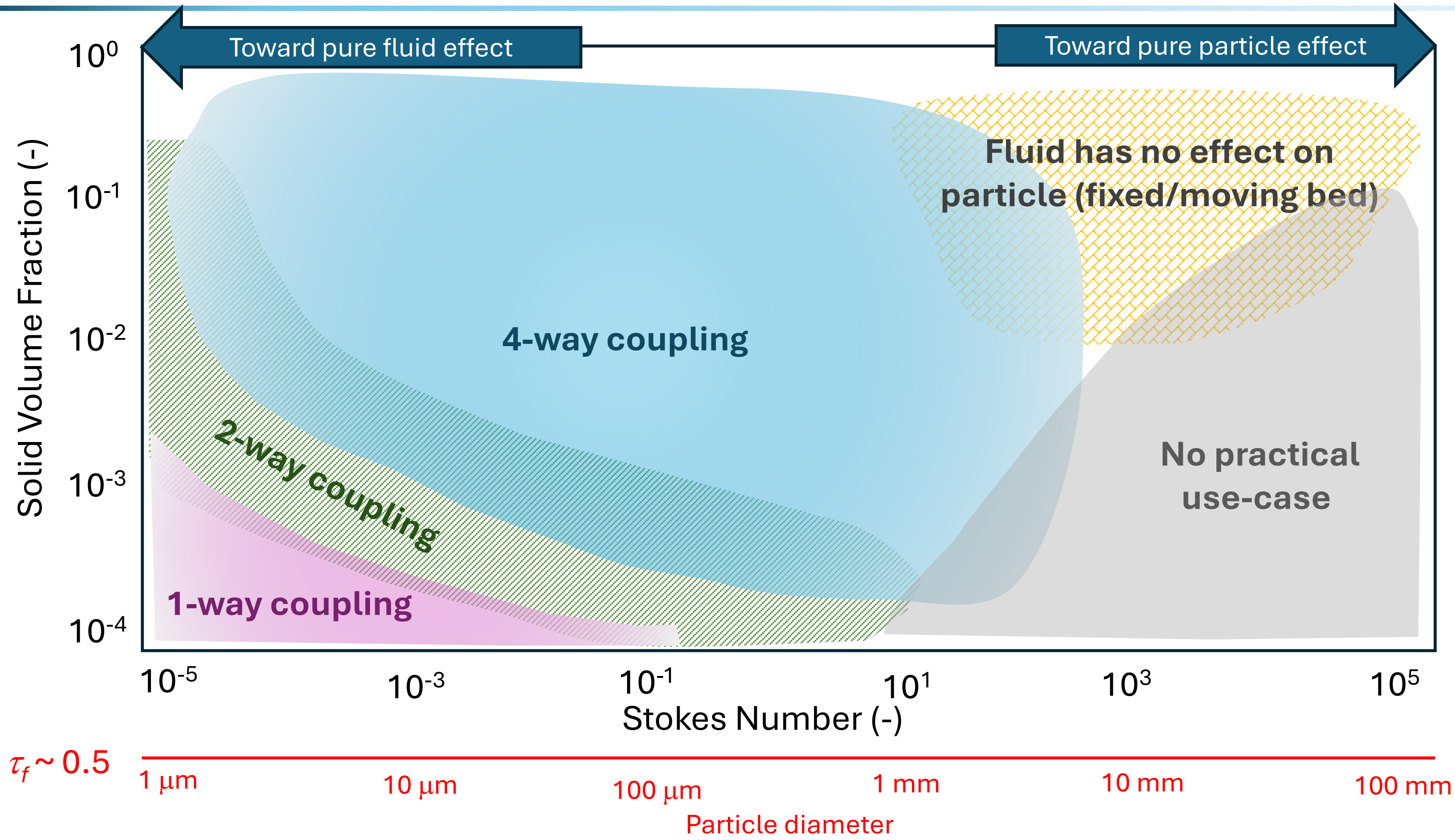
Fluid-Particle Coupling

Types of Coupling (Fluid-particle)

- One-way:
  - Motion of particles are primarily affected by motion of fluid while motion of particles has negligible effect on the fluid
  - small particles and low concentration
- Two-way:
  - Mutual effect of particles and fluid on each other.
  - Larger particles with low concentration
- Four-way:
  - Mutual effect of particles and also particle-particle interactions
  - Larger particles with low to high concentration

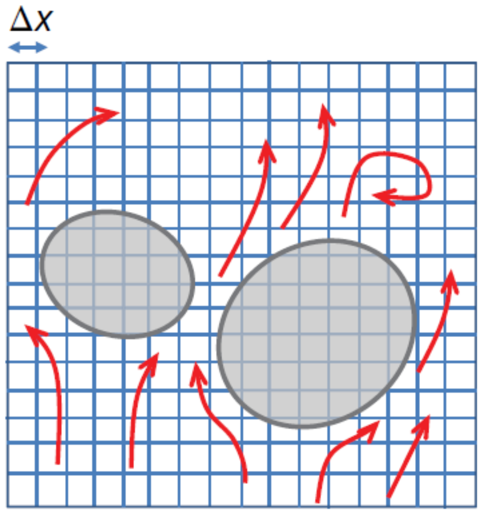
Coupling map (for air)



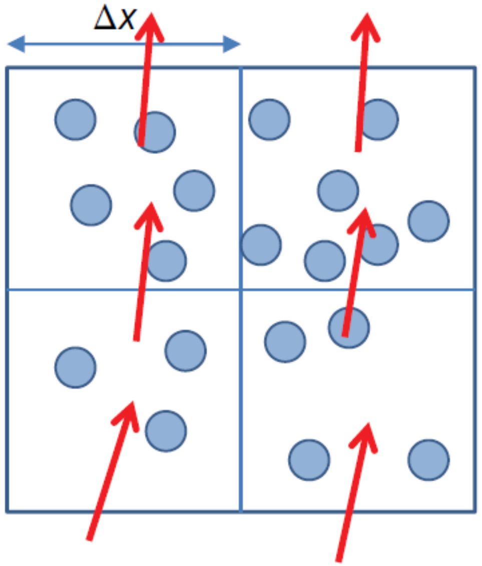
$$St_{mom} = \frac{\tau_p}{\tau_f}$$

4-way CFD-DEM coupling

- Resolved CFD-DEM:



- Unresolved CFD-DEM:



Unresolved CFD-DEM

- Fluid phase equations:

$$\frac{\partial\left(\rho_f \varepsilon_f\right)}{\partial t} + \nabla.\left(\rho_f \varepsilon_f \vec{u}\right) = 0$$

$$\frac{\partial\left(\rho_f \varepsilon_f \vec{u}\right)}{\partial t} + \nabla.\left(\rho_f \varepsilon_f \vec{u}\vec{u}\right) = -\varepsilon_f \nabla p - \varepsilon_f \nabla.\vec{\tau}_f - \vec{F}^A + \rho_f \varepsilon_f \vec{g}$$

$$\vec{F}^A = \frac{1}{V_{cell}} \sum_{i=1}^{k_v} \left(\vec{f}_i^d + \vec{f}_i^u + \vec{f}_i^l\right)$$

- Particle phase equations:

$$m_i \frac{d\vec{v}_i}{dt} = \vec{f}_i^{f-p} + \sum_{j \in CL_i} \left(\vec{f}_{ij}^c + \vec{f}_{ij}^{nc}\right) + \vec{f}_i^g$$

$$\vec{f}_i^{f-p} = \vec{f}_i^d + \vec{f}_i^u + \vec{f}_i^{\nabla p} + \vec{f}_i^{\nabla.\vec{\tau}_f} + \vec{f}_i^l$$

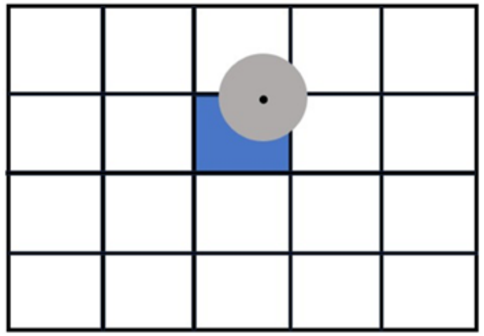
$$I_i \frac{d\vec{\omega}_i}{dt} = \sum_{j \in CL_i} \vec{M}_{ij}^c + \vec{M}_i^{f-p}$$

Mapping particle data onto cells

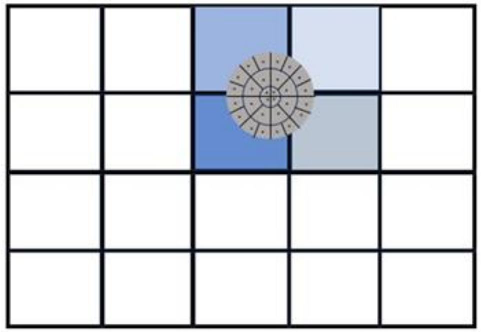
- Two main coupling parameters are calculated using a mapping method:

$$\varepsilon_f = \frac{1}{V_c}\sum_{i\ in\ LST_c} \lambda_i V_{p,i} \qquad \vec{F}^{A} = \frac{1}{V_c}\sum_{i\ in\ LST_c} \lambda_i \vec{f}^{\,f-p}$$

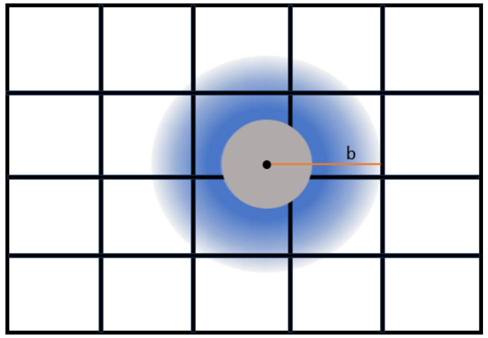
PCM



Divided volume 29



Gaussian kernel



Available mapping methods in PF

- self (PCM): when cell-to-particle size is large (>6)
- subDivision29 (porosity only): when cell-to-particle size > 3
- Gaussian:
- adaptiveGaussian (the best): For orthogonal mesh with any aspect ratio and cell-to-particle size ratio
- GaussianIntegral: similar to adaptiveGaussian, but the error is a bit higher
- diffusion: for non-orthogonal meshes (set standard deviation to 3-6 times particle diameter0

Calculation sequence in CFD-DEM