A CFD based comparison of mixing due to regular and random cylinder arrays

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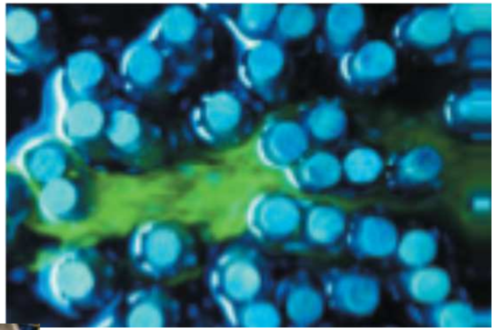
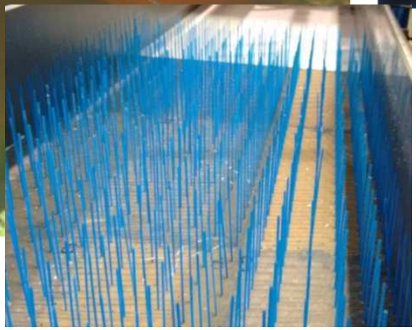
Introduction

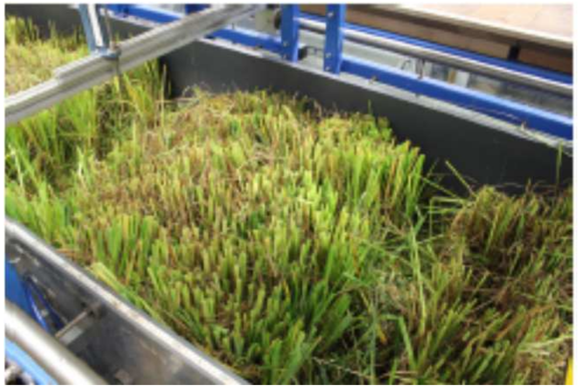
Wooden Dowels (Tanino and Nepf, 2009)



Real Vegetated Pond (Taken by Ian Guymer)



Drinking Straws (West, 2016)



CFD could provide an alternative complementary method

Real Vegetation (Sonnenwald et al. 2017)

Aims of this Study

- To examine the capability of CFD models for simulating flow and solute transport within regular and random cylinder arrays

- To provide a direct comparison between regular and random arrays

- To investigating the effect of injection location

Flow and Mixing Principles

Flow:

- 2D Navier-Stokes

$$\frac{\partial u_x}{\partial x} + \frac{\partial u_y}{\partial y} = 0$$

$$u_x \frac{\partial u_x}{\partial x} + u_y \frac{\partial u_x}{\partial y} = -\frac{1}{\rho}\frac{\partial p}{\partial x} + \nu\left[\frac{\partial^2 u_x}{\partial x^2} + \frac{\partial^2 u_x}{\partial y^2}\right] + S_x$$

$$u_x \frac{\partial u_y}{\partial x} + u_y \frac{\partial u_y}{\partial y} = -\frac{1}{\rho}\frac{\partial p}{\partial y} + \nu\left[\frac{\partial^2 u_y}{\partial x^2} + \frac{\partial^2 u_y}{\partial y^2}\right] + S_y$$

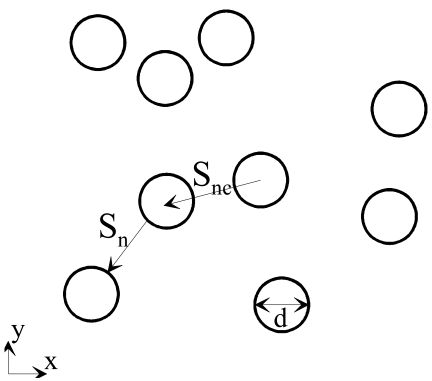
Mixing:

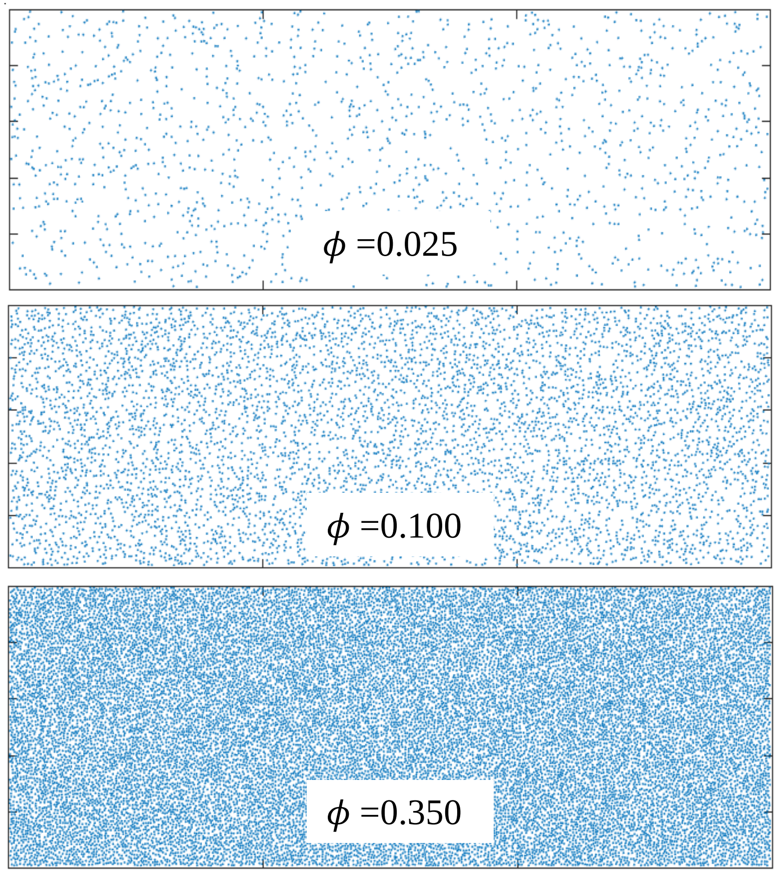
- Scalar transport/2D Advection-dispersion equation

$$\frac{\partial c}{\partial t} + u\frac{\partial c}{\partial x} + v\frac{\partial c}{\partial y} = D_x\frac{\partial^2 c}{\partial x^2} + D_y\frac{\partial^2 c}{\partial y^2}$$

Array Describing Parameters

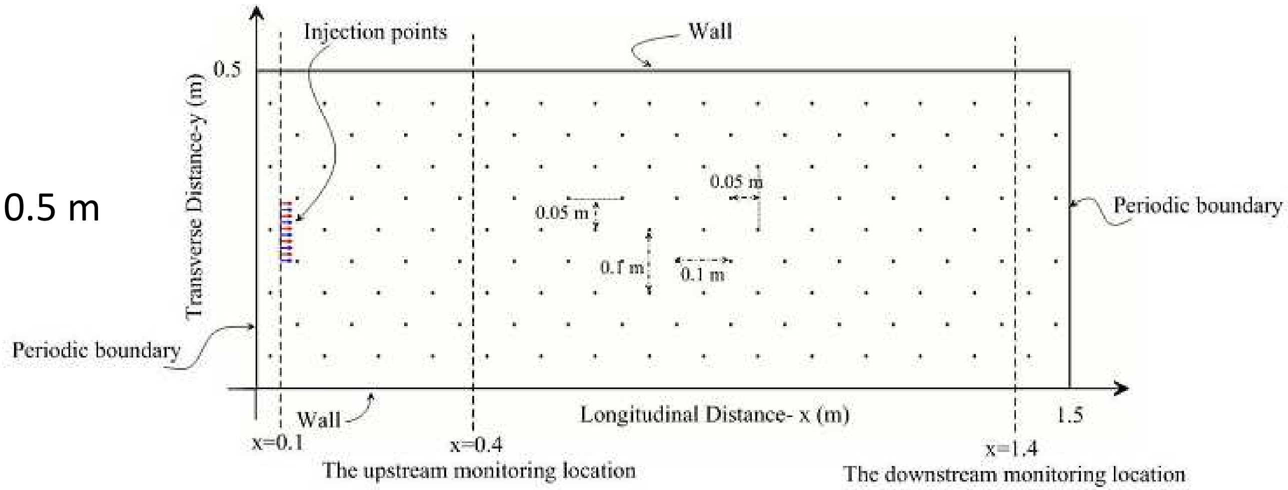
- d
- Re_d
- $\phi = \frac{m\pi d^2}{4}$
- S_{nc}
- S_n
- Re_{Snc} & Re_{Sn}

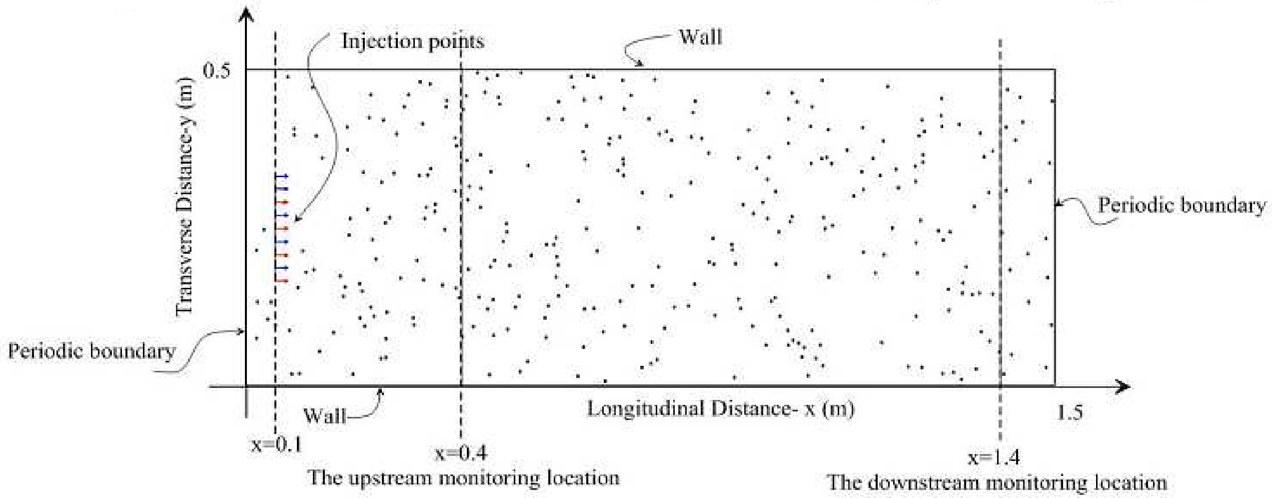




Geometries

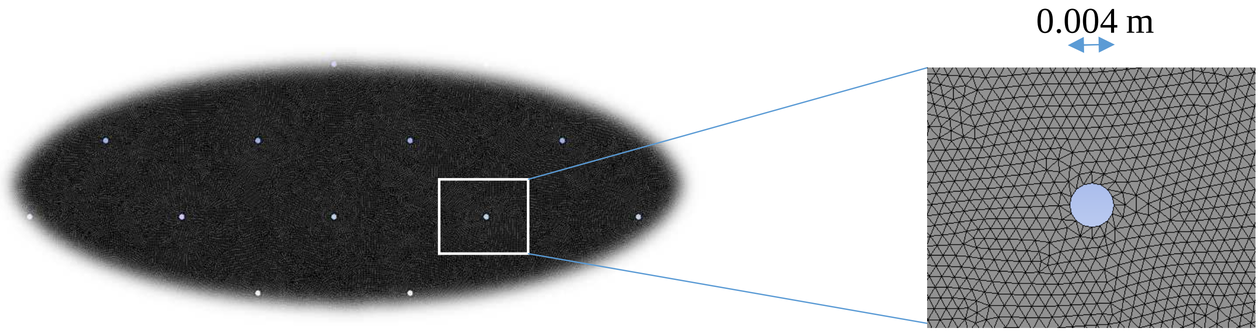
Ansys Fluent 16.1
Two dimensional model
Channel dimensions: 1.5 m × 0.5 m
Test section length: 1 m





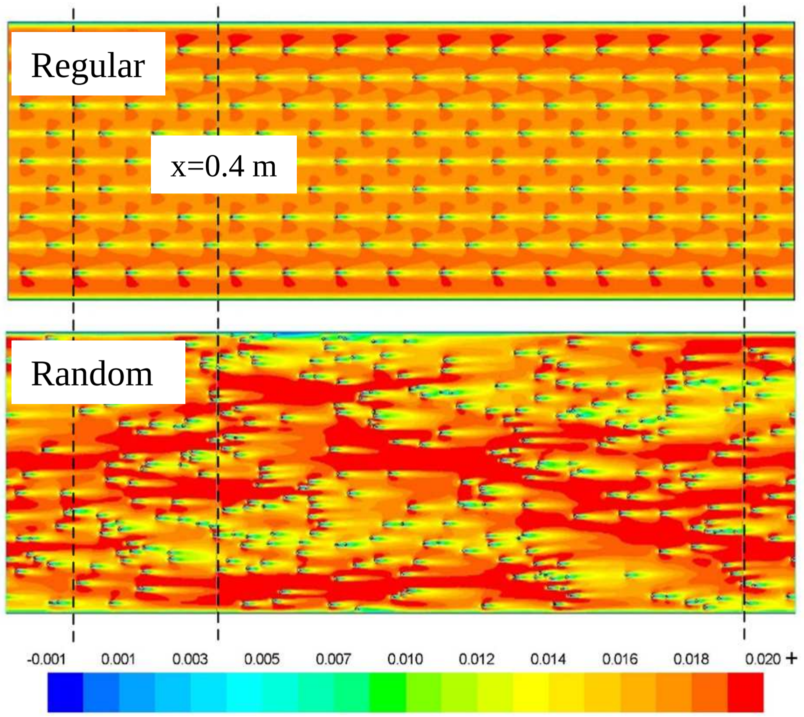
d= 0.004 m
Ø=0.005
S_{nc}(regular)=0.071 m
S_{nc}(random)=0.025 m

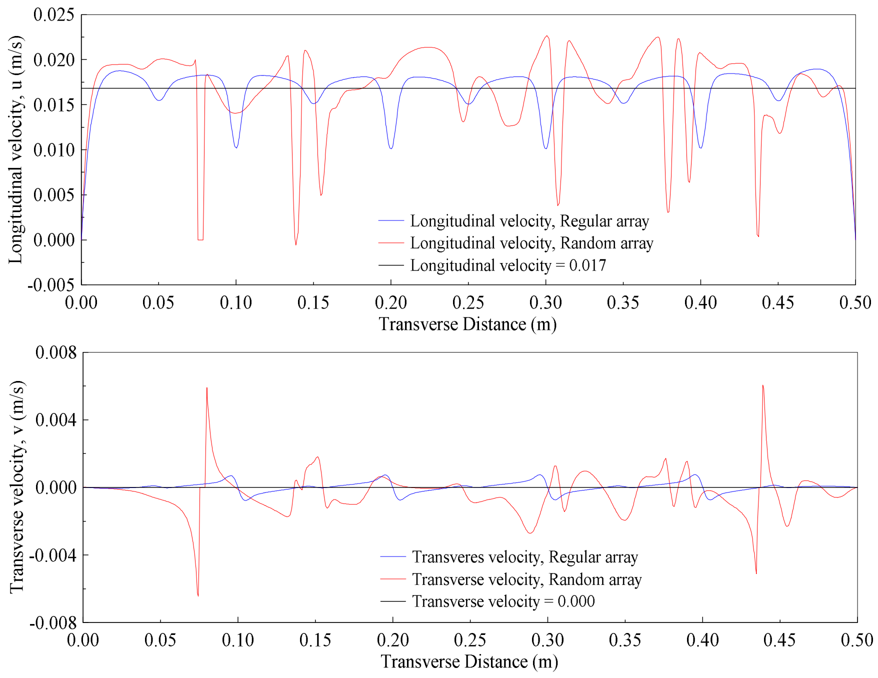
Mesh and Model Properties



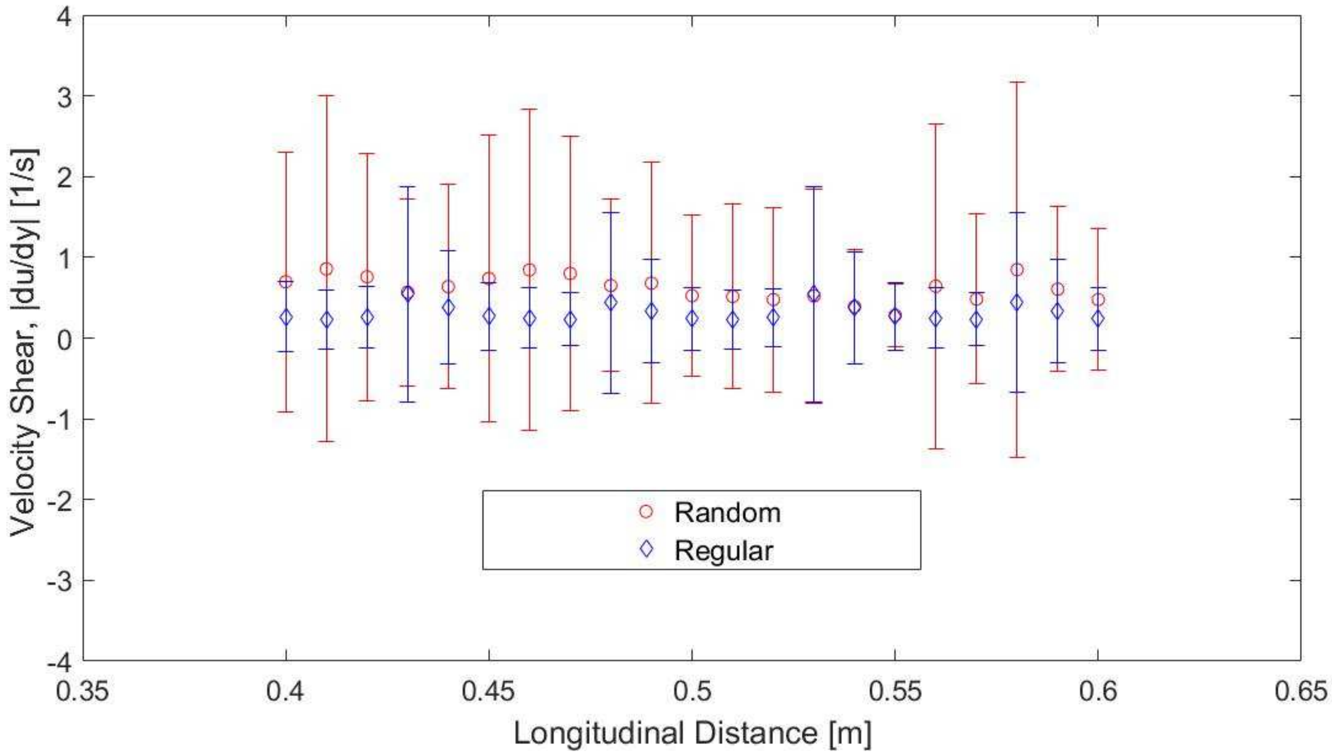
- Mesh cell size=0.001 m triangular mesh (confirmed to be mesh-independent)
- Approximately 1.6×10^6 cells for each channel
- Reynolds Stress Model (RSM)
- The enhanced wall function for walls
- The second order up-wind method for discretization

Flow Field Results

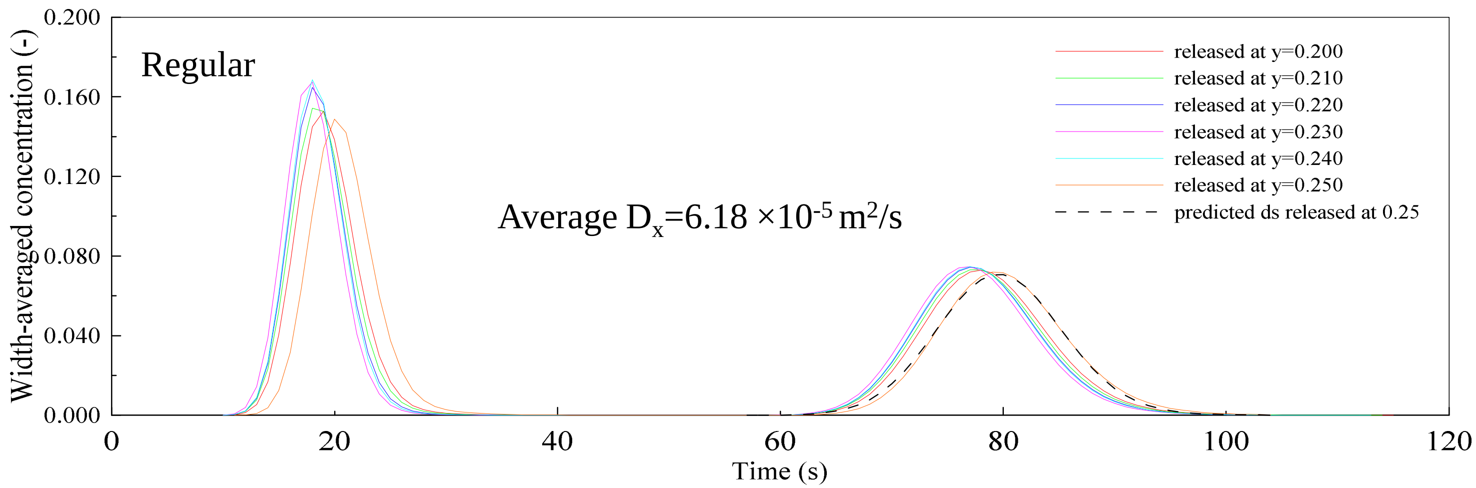


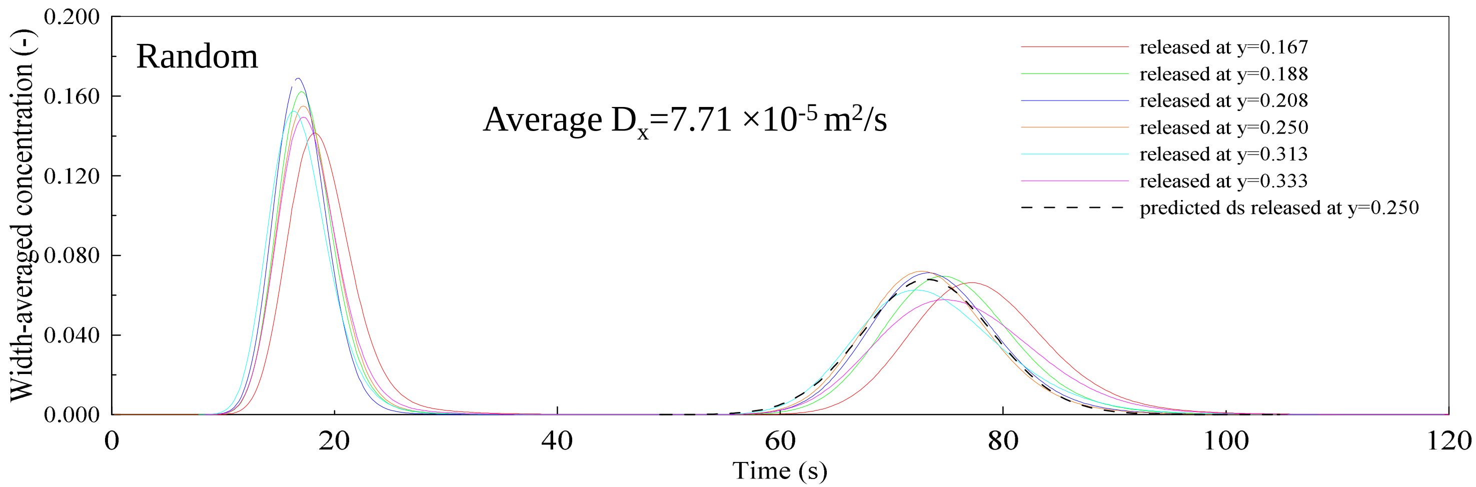


Velocity Shear |du/dy|

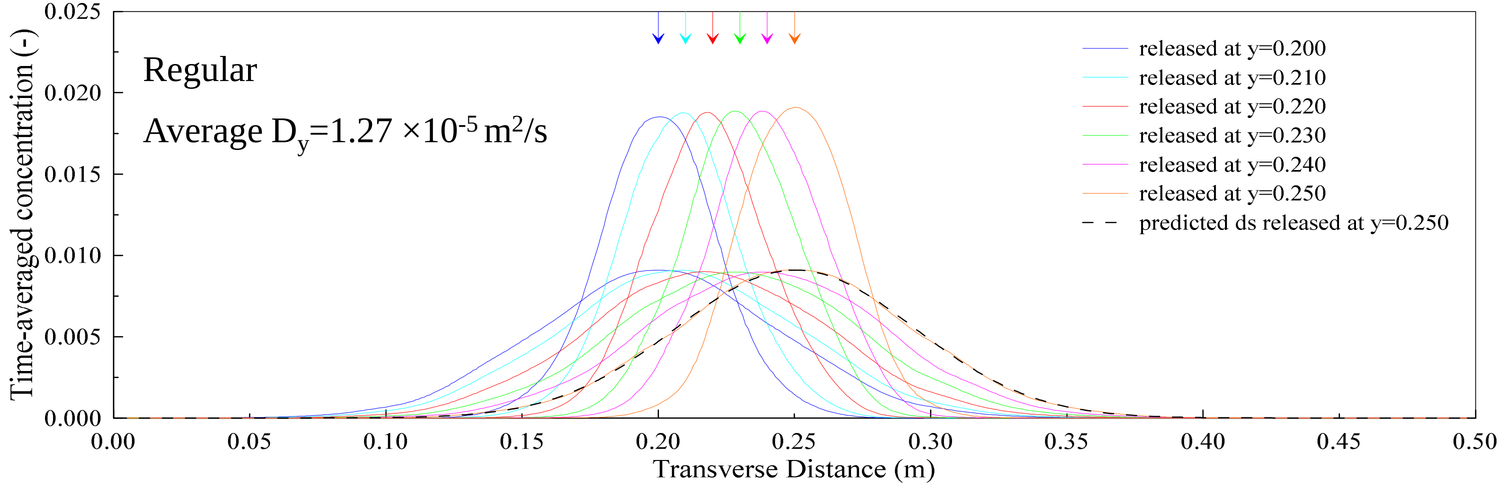


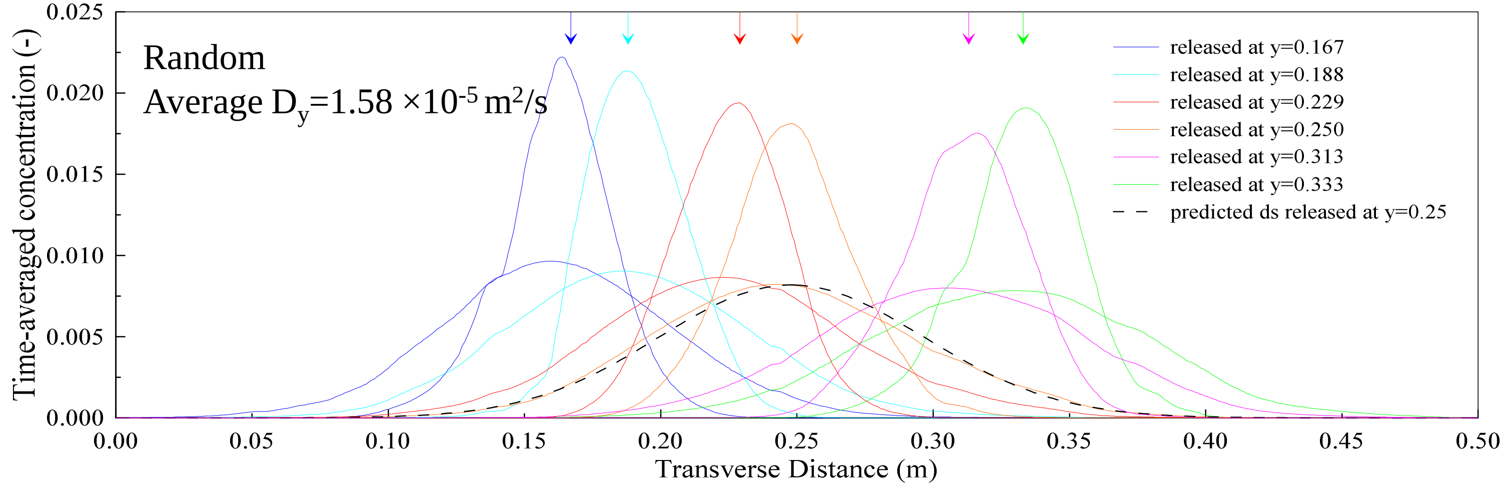
Longitudinal Mixing Results

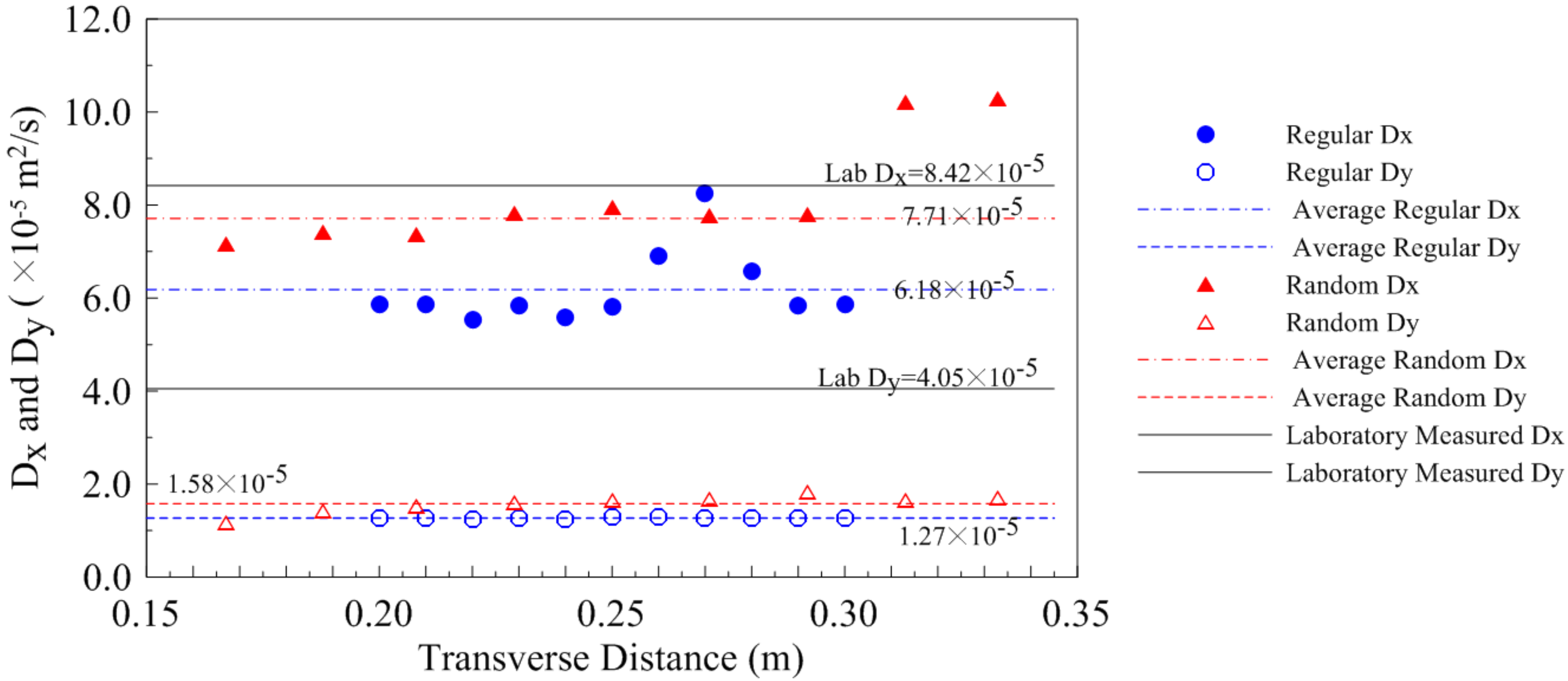




Transverse Mixing Results







12.0
10.0
8.0
6.0
4.0
2.0
0.0
0.15
0.20
0.25
0.30
0.35
Transverse Distance (m)
Dx and Dy (×10-5 m2/s)
Lab Dx=8.42×10-5
7.71×10-5
6.18×10-5
Lab Dy=4.05×10-5
1.58×10-5
1.27×10-5
Regular Dx
Regular Dy
Average Regular Dx
Average Regular Dy
Random Dx
Random Dy
Average Random Dx
Average Random Dy
Laboratory Measured Dx
Laboratory Measured Dy

Conclusions

- A direct comparison between flow and mixing in regular and random arrays has been made.
- Greater transverse and longitudinal dispersion in the random array was observed.
- The difference is attributed to greater levels of velocity shear in the random array.
- The capability of 2D RSM models along with scalar transport in modelling mixing within cylinder arrays has been demonstrated.
- The next step is to use this tool to investigate the effects of different d and Ø values in random arrays.

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