CFD Analysis of Detection Region Placement in Low-Cost OPCs

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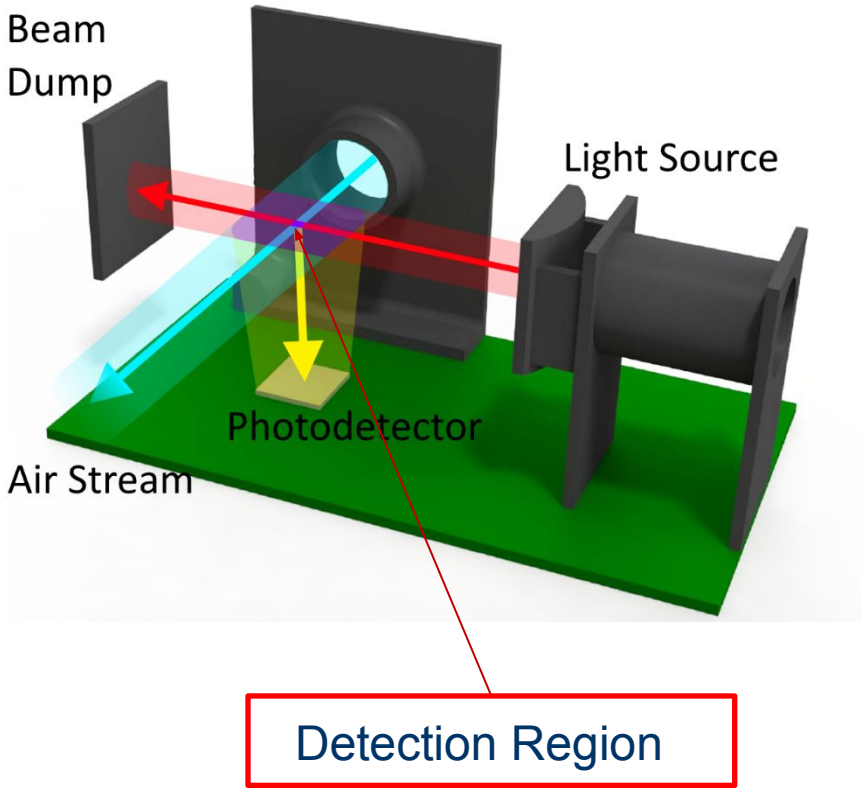
Research Focus

Optical Particle Counters (OPCs) are used to detect particulate matter (PM) in the environment

Need rigorous analysis of OPCs

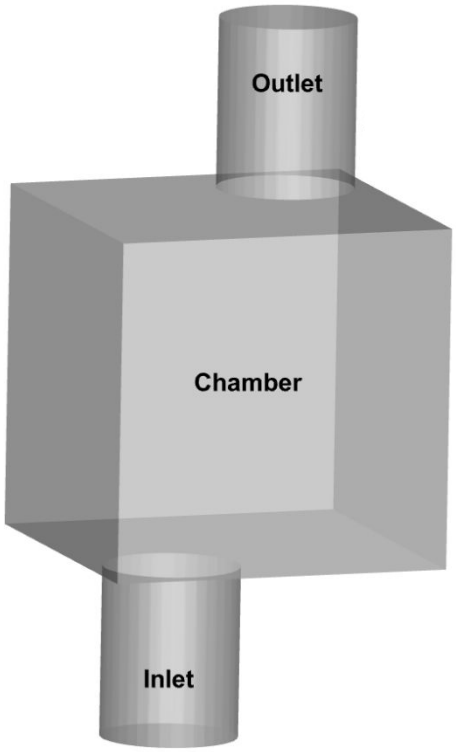
- Is ambient concentration the same as measured concentration?
- Is location of detection region important?
- Is fan flow rate important to control?
- Is the flow path critical for design?



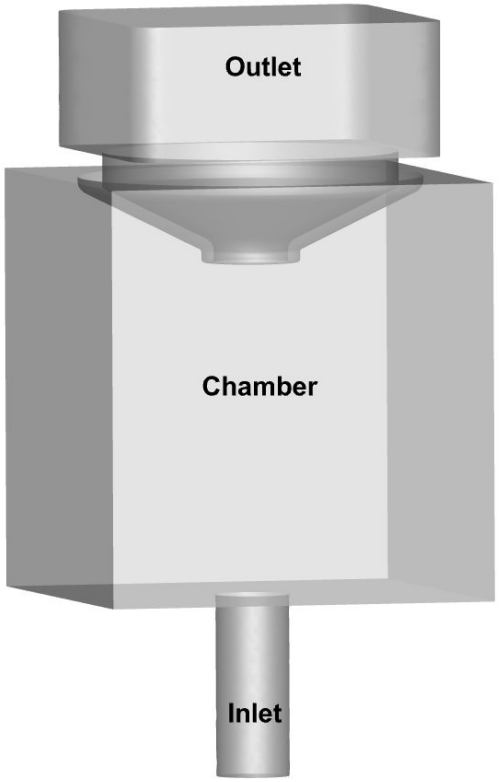
Current Work

Analysis of PM concentration in regions

- Two Geometries
  - Simple chamber
  - Commercial OPC
- Two CFD Packages for comparison
  - CONVERGE Studio
  - ANSYS Fluent



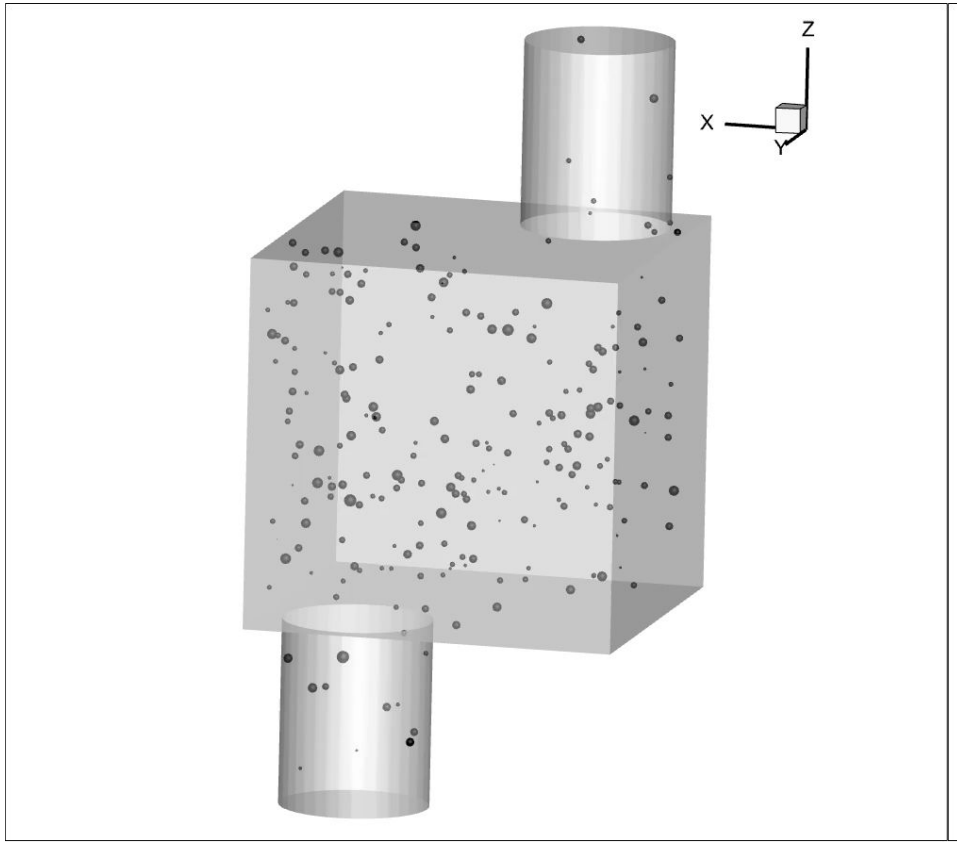
Simple Chamber



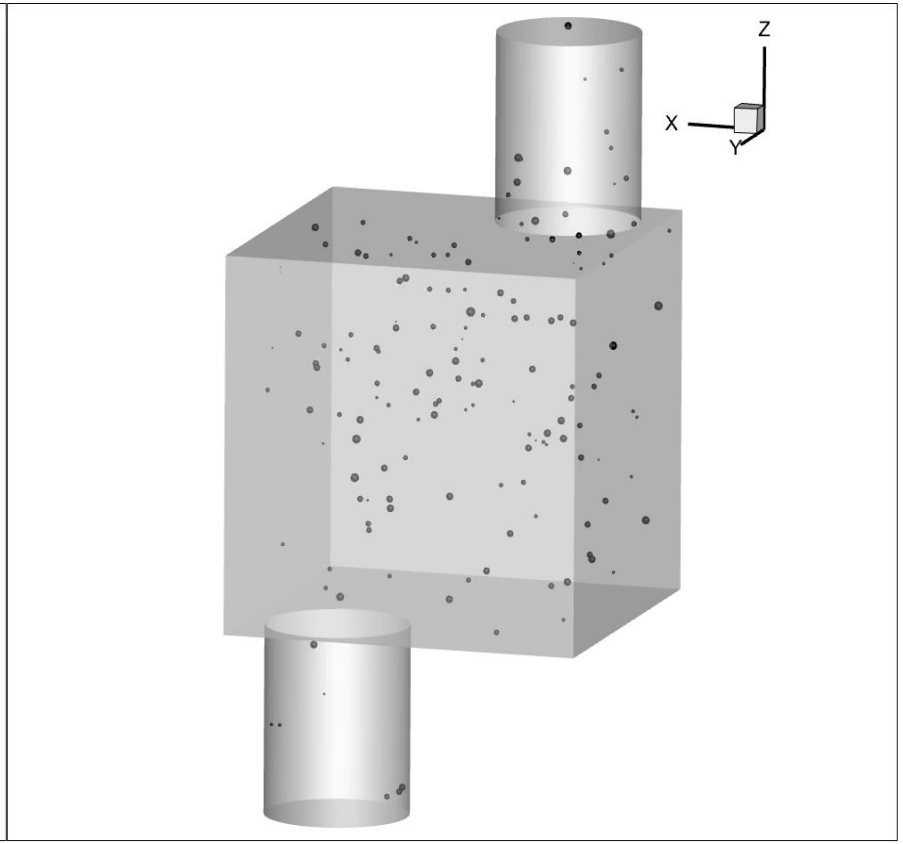
Commercial OPC

CFD Simulation- 2 packages

CONVERGE Studio



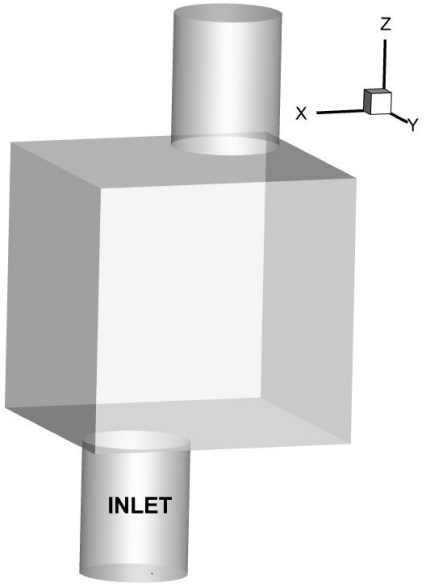
ANSYS Fluent

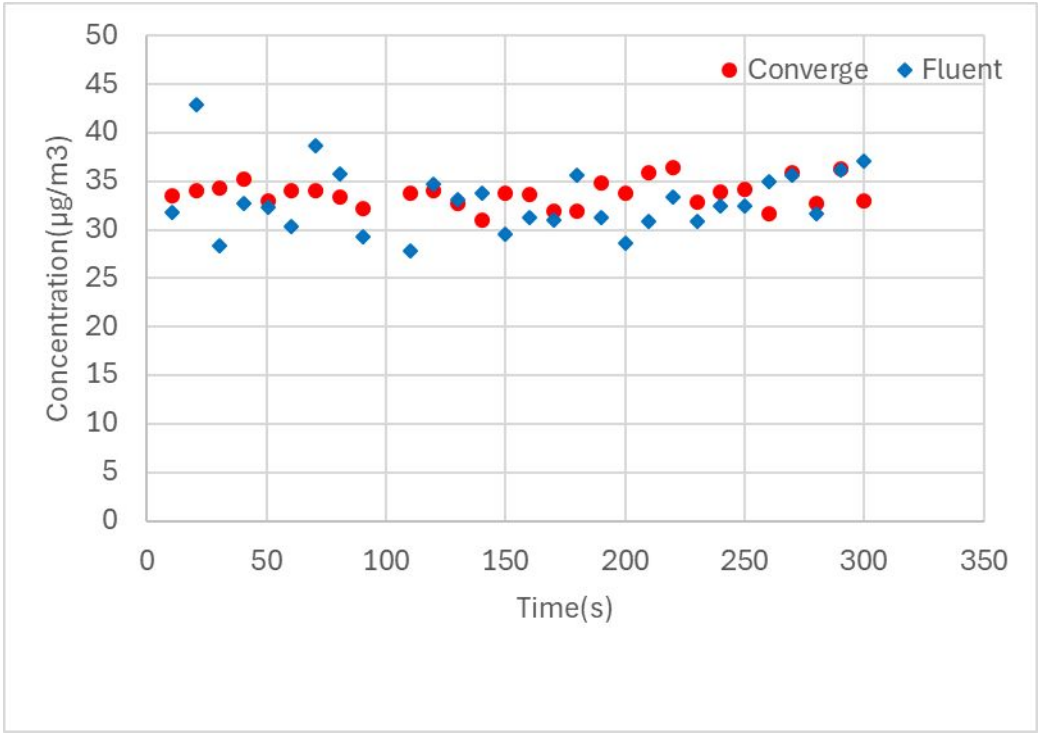


Target concentration of 35 $\mu g/m^3$
($PM_{2.5}$ daily exposure by EPA)

- Velocity of 0.023 m/s
- No gravity
- Particles are scaled for viewing

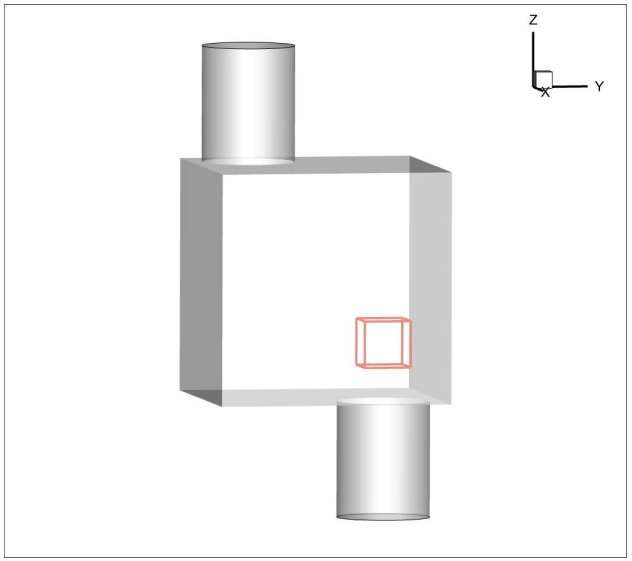
Simple Geometry- inlet

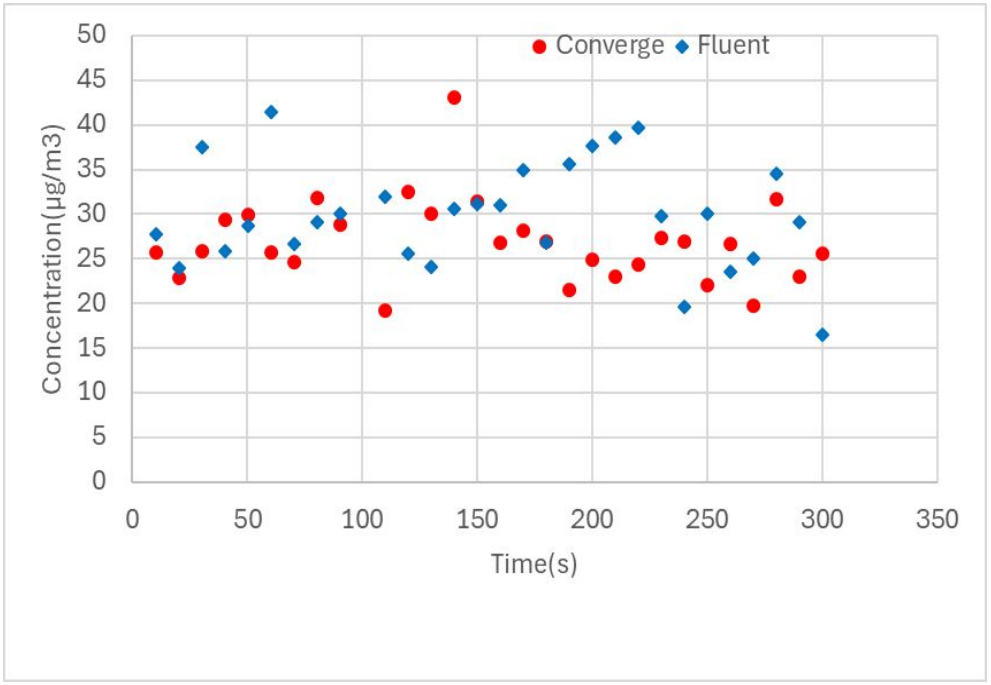




- Reached quasi-steady nearly 100 sec
- Inlet concentrations are similar for both CFD packages.

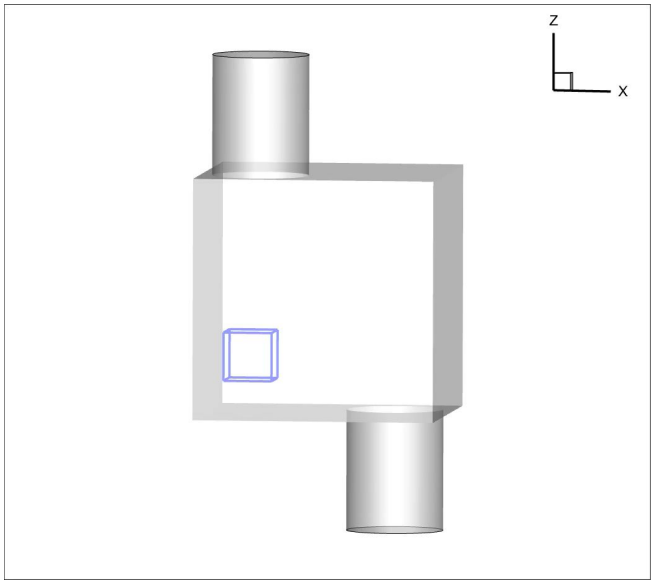
Simple Geometry- Region 1

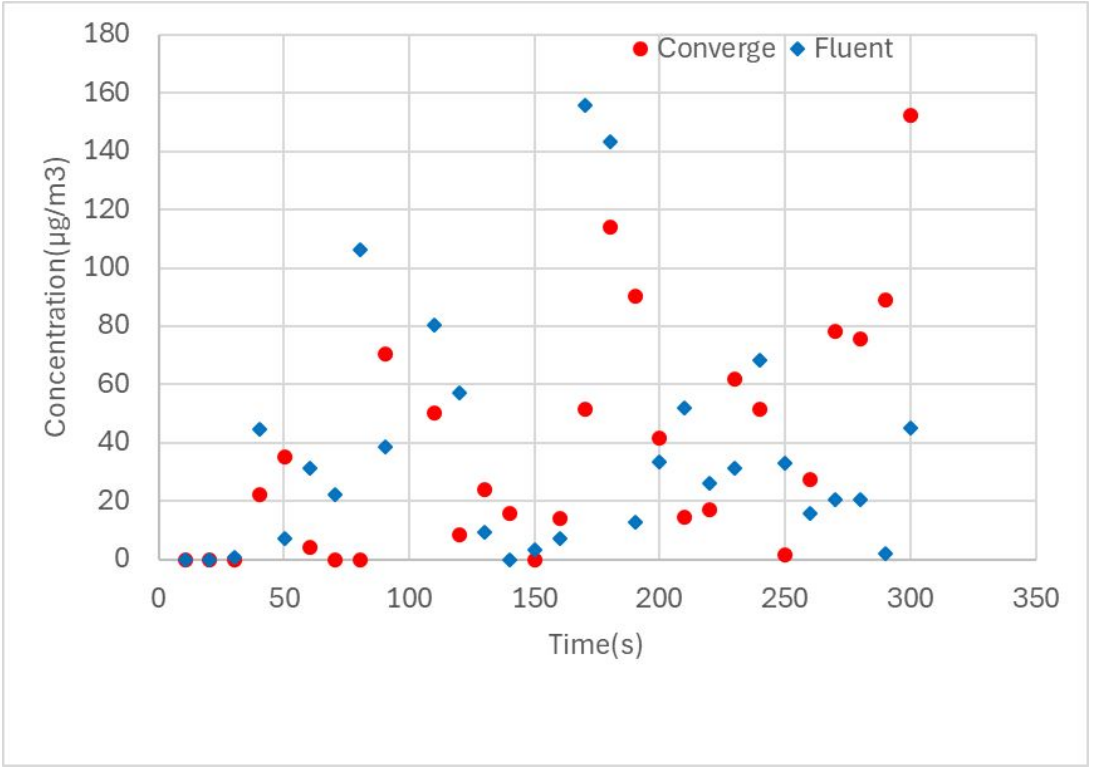




- Concentrations similar to inlet concentration for both simulations
- Some spread in both simulations
- Averaging: 30 $\mu g/m^3$ (Fluent) and 27 $\mu g/m^3$ (Converge)
- Averaging with long time provides reasonable concentration
- A potential detection region- need to consider possible light interference

Simple Geometry- Region 2

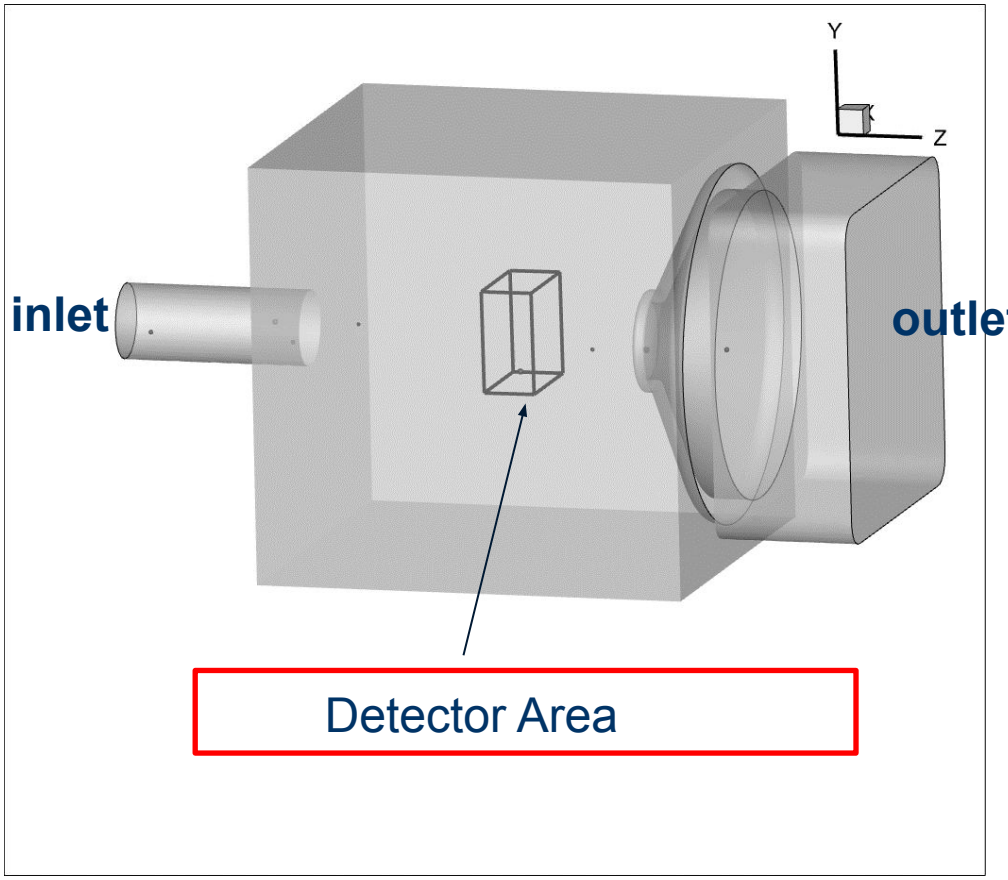




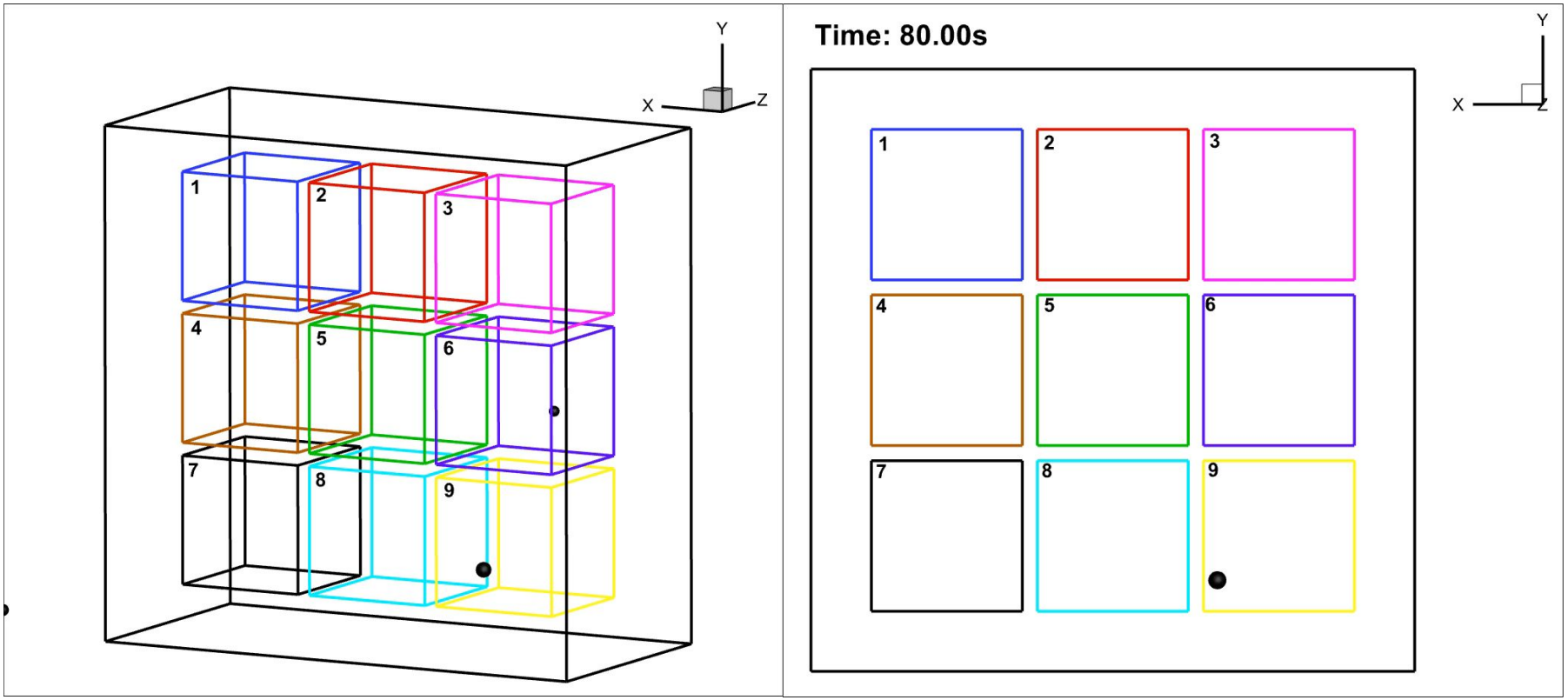
- Large spread in concentrations for both simulations
- Several times, concentrations are much higher than inlet concentration- due to poor flow in region
- Not a good potential detection region

Commercial OPC

- No tortuous path; direct flow inlet to outlet
- Expanded outlet diameter
- Max particle size - 2.5 μm
- Target inlet concentration of 10 $\mu g/m^3$
- 9 sub-regions analyzed in detector area



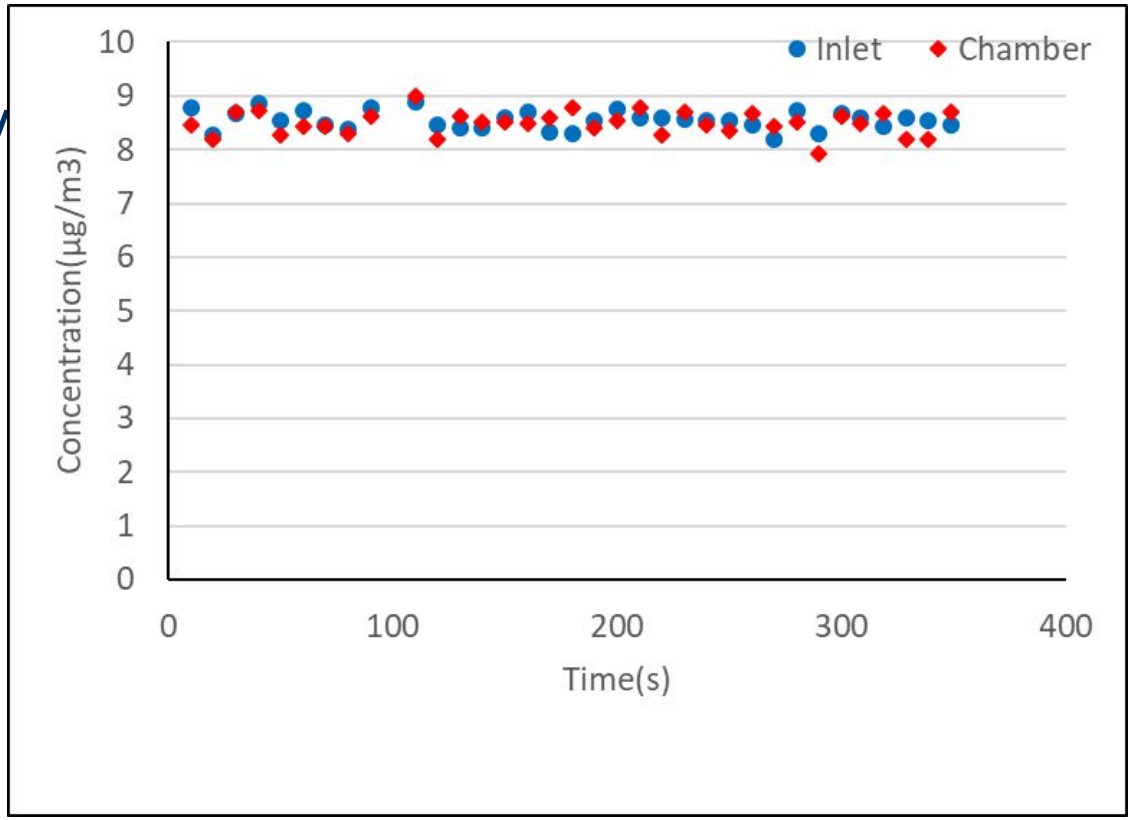
Commercial OPC- Detection Area



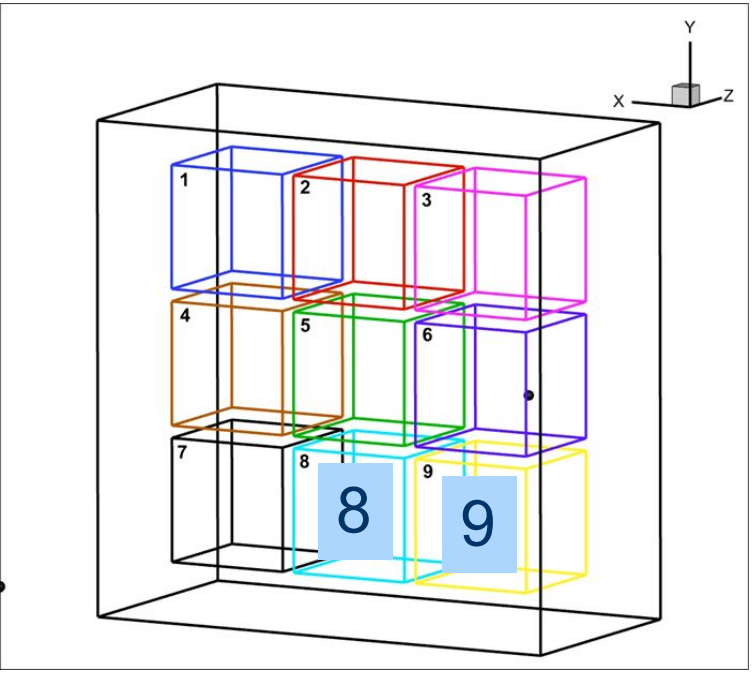
- Ansys Fluent Analysis
- Typically, one particle at a time in a region

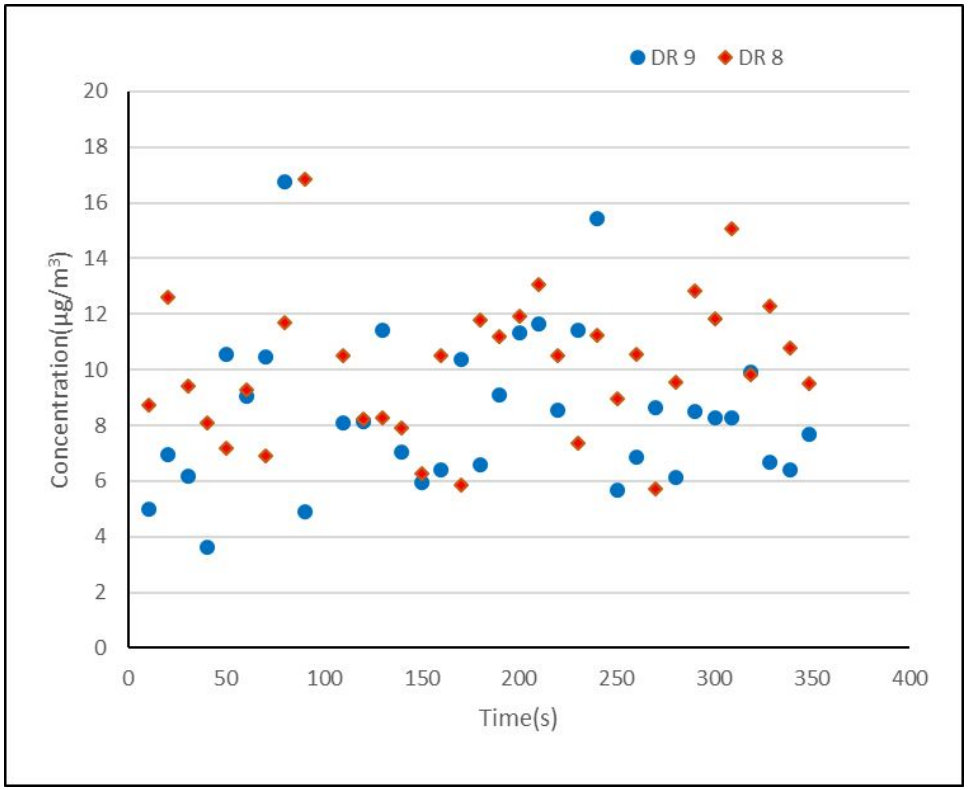
Commercial OPC- inlet/chamber

- Reached quasi-steady immediately
- Inlet and chamber concentrations are similar
- Very little concentration variation



Commercial OPC



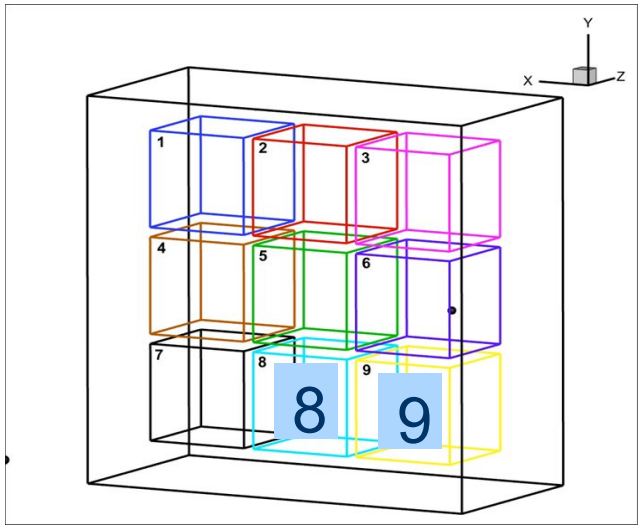


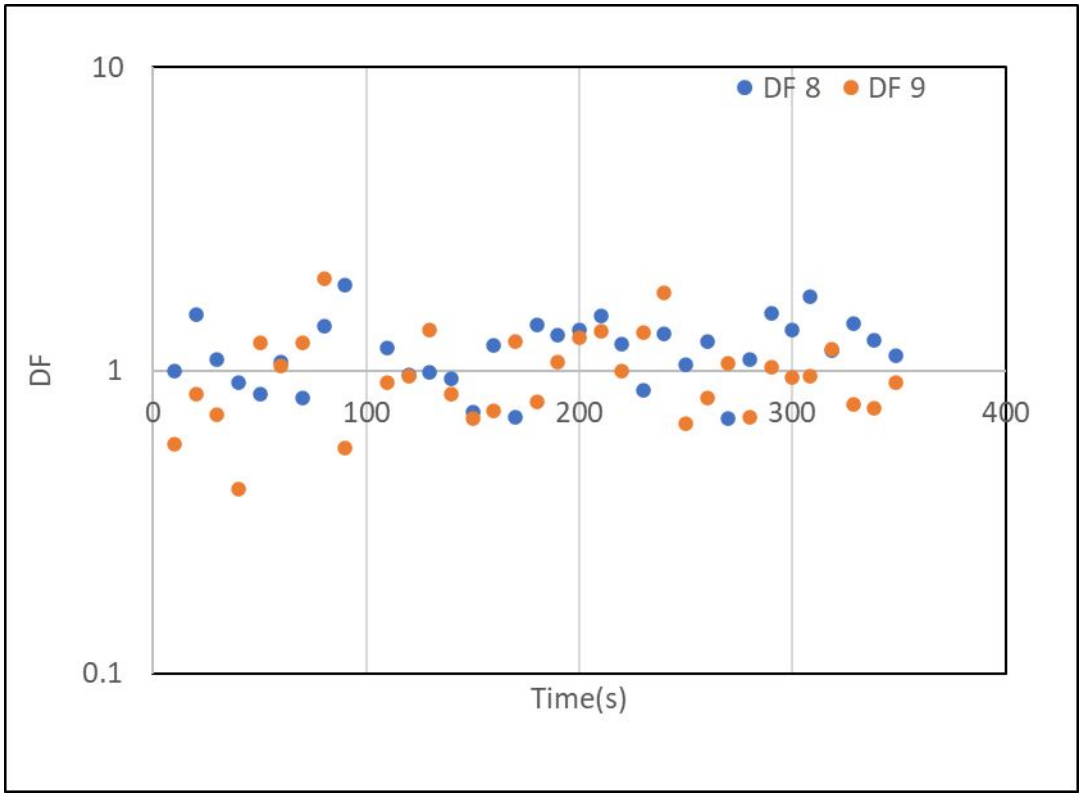
- Similar concentrations and variations in each region
- Average: 10 μg/m^3 (Region 8) and 8.5 μg/m^3 (Region 9)
- Averaging with long time provides reasonable concentration
- Similar results for other regions

Commercial OPC Detection Factor

$$DF = \frac{region\ concentration}{Inlet\ Concentration}$$

Ideally, DF = 1





- Both regions have fluctuating DF
- Large time averaging will remove noise; Average of 1.2 (Region 8) and 0.99 (Region 9).
- Similar results for other regions

Conclusions

- Used 2 CFD packages to cross-check results of each other; similar results with both packages
- CFD is beneficial for analyzing concentrations within an OPC geometry.
- Geometry can significantly affect the concentration, with large variations depending upon the region.
- OPC geometry and flow path is important to consider when designing an OPC
- Concentration and detection factor analysis is beneficial for determining best place for detector

Future Work

- Simulate more commercially available OPCs
- Provide design guidelines based on simulation results
- Develop low-cost calibration system for commercial OPCs
- Perform experimental work to validate computational results

Acknowledgments

Office of Research Computing

Questions?