$PM_{2.5}$ Concentration Profile around A SALSCS/AMSA: A Numerical Study under Different Ambient Conditions

Qingfeng Cao, Sheng-Chieh (Shawn) Chen, Lian Shen, David Y.H. Pui

May 5th, 2017

51st Review Meeting, Center for Filtration Research
Mechanical Engineering Department, University of Minnesota

Center for Filtration Research

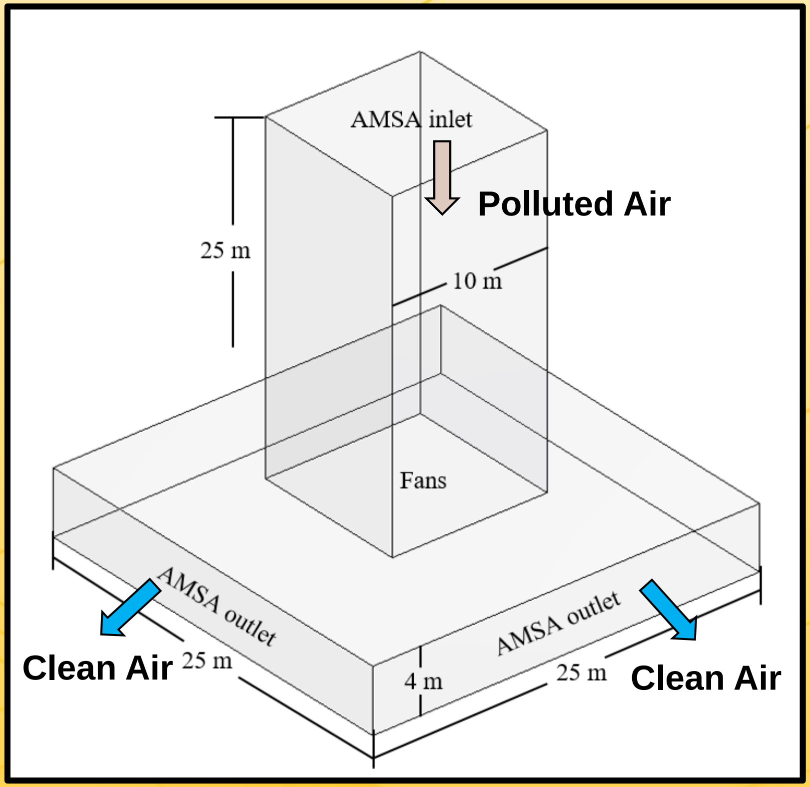
University of Minnesota

Outline

- Introduction;
- Model description;
- In a quiescent atmosphere;
- Under uniform ambient wind speeds;
- Summary and future work.

Introduction

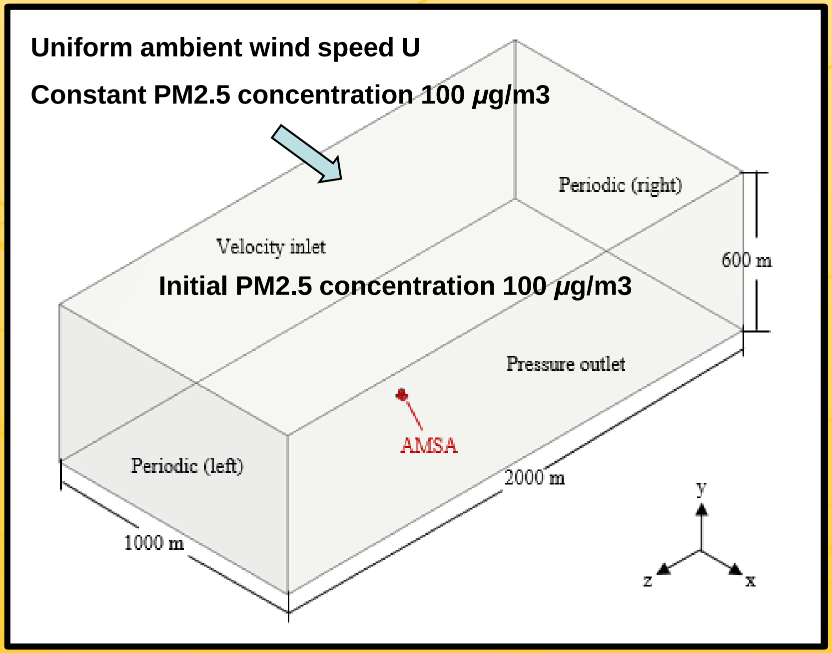
- Picture showing dimensions and geometry of AMSA in the numerical model;
- Polluted air flows in through the inlet at the top;
- Clean air is delivered through the outlet at the base;
- To calculate the $PM_{2.5}$ concentration profiles around AMSA;
  - ✓ Under different idealized ambient conditions.
  - ✓ Using numerical method.
- ***Objective*: Conduct numerical experiments to determine the $PM_{2.5}$ concentration profiles around AMSA.**



Model Description

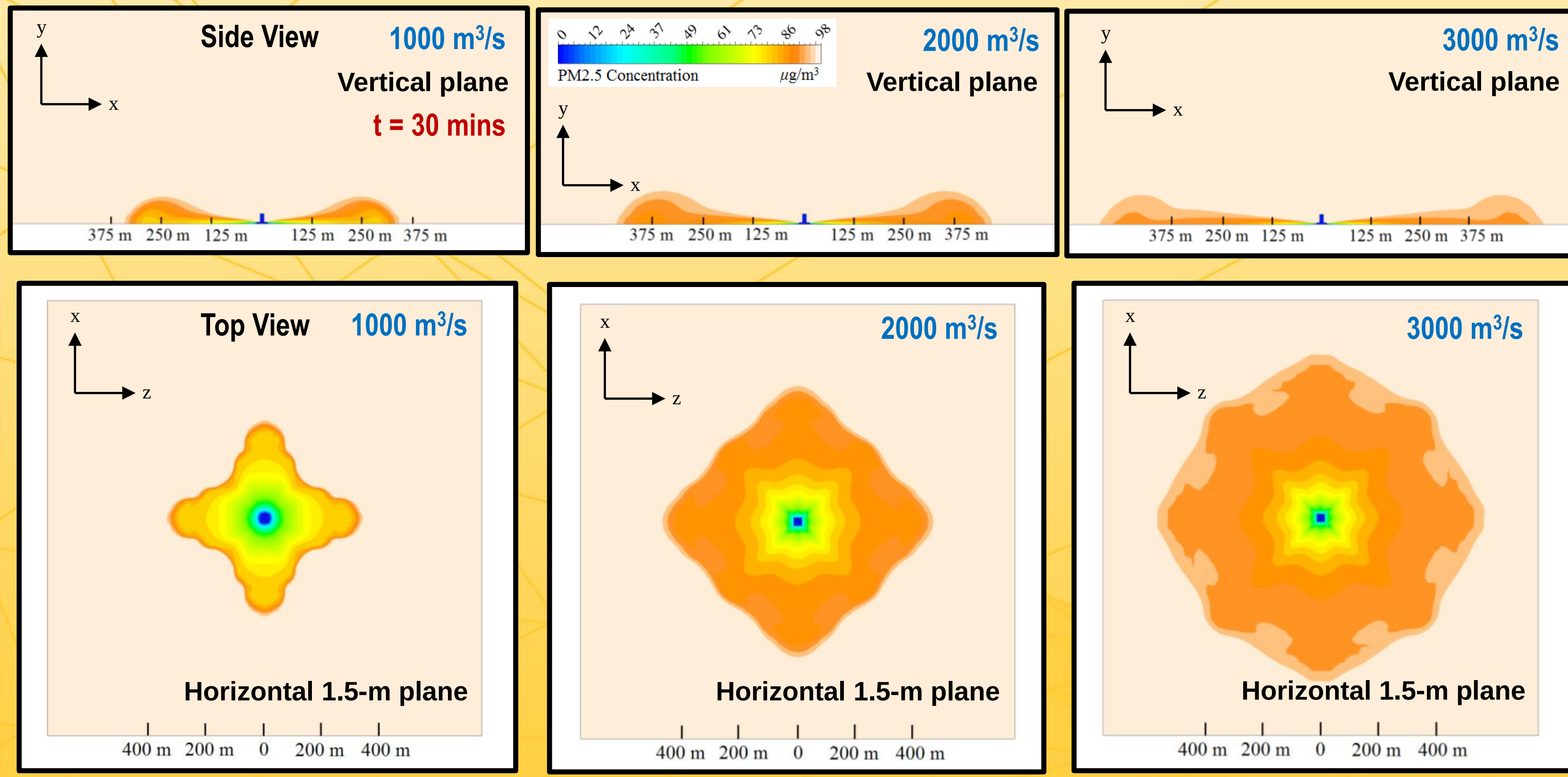
- Reynolds number larger than 10^6, indicating a turbulent flow field.
- 3D incompressible Reynolds-Averaged Navier Stokes (RANS) equations.
- k-ε 2-equation turbulent model for Reynold stress closure.
- Assuming mixture of polluted ambient air and clean air from AMSA.
- Ambient $PM_{2.5}$ concentration 100 $\mu g/m^3$; clean air 0 $\mu g/m^3$.
- Physical air properties are set under -1.5 ºC (29.3 ºF).
- Species transport equation is solved for polluted ambient air.

- In a quiescent atmosphere.
  - ✓ Transient model
- Or under different uniform ambient velocities.
  - ✓ Steady-state model



$PM_{2.5}$ Concentration Contours in Quiescent Atmosphere

- Below are the contours of $PM_{2.5}$ concentration in a vertical plane at different flow rates.



- Above are the horizontal contours at 1.5-m plane above the ground.

$PM_{2.5}$ Concentration Profiles in Quiescent Atmosphere

- Figure showing the $PM_{2.5}$ concentration vs. distance for 4 different system flowrates.
- Simulation time long enough so that the concentration profiles reach steady state inside the radius of 500 m.

✓ Lower flowrate achieves lower $PM_{2.5}$ concentration.

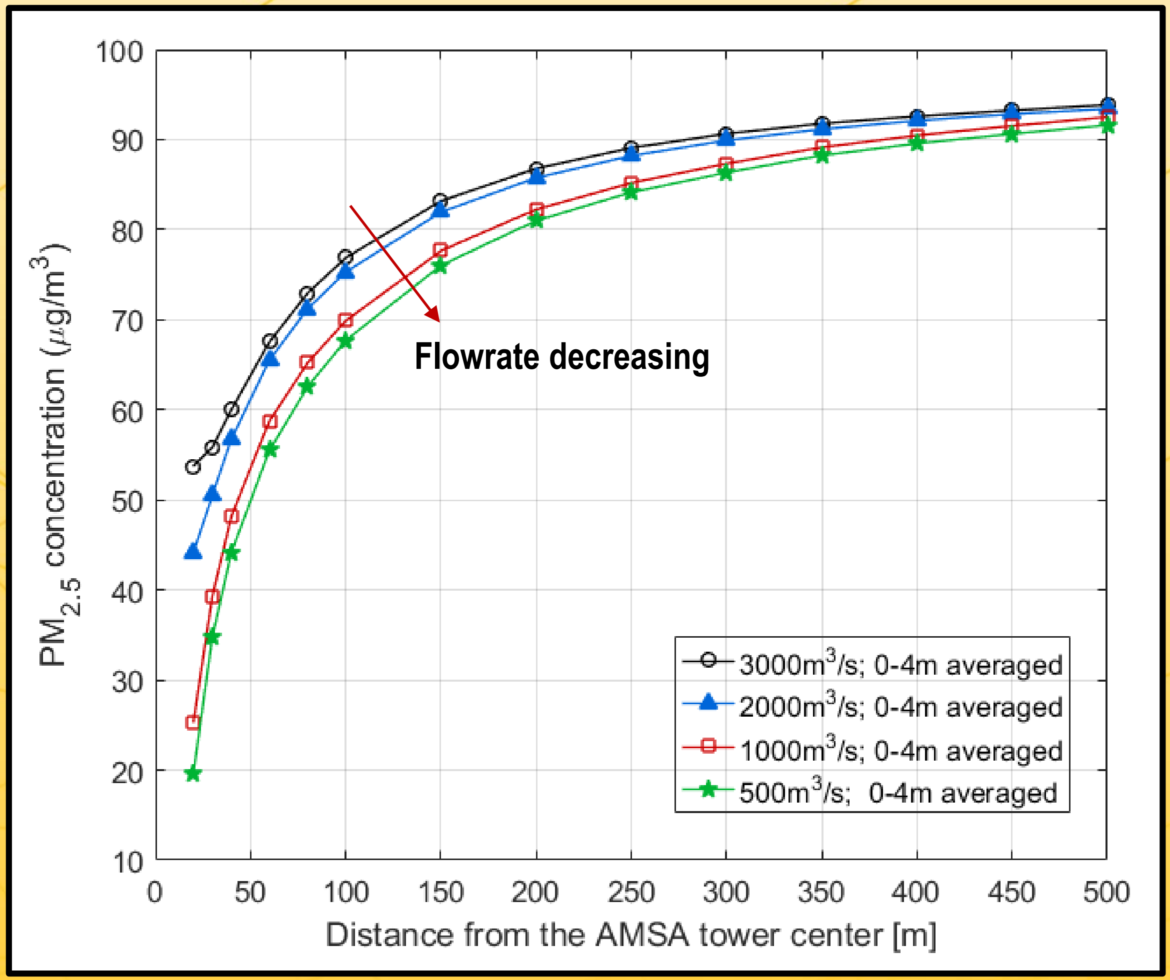
➢ Here a simple explanation:

- Flowrate, *Q*; outlet velocity, *v*; time level *t*.
- If assume clean air flow velocity, v, and plume height, *h*, stay constant then the volume containing clean air is

$$V = \pi (vt)^2 h$$

- Clean air concentration calculated as

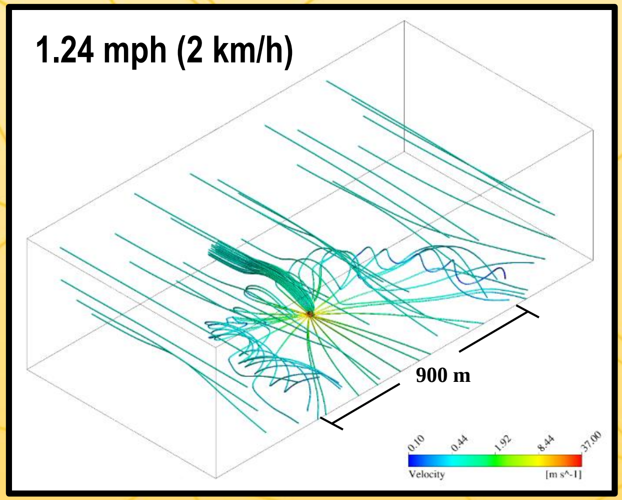
$$C_{clean} = Qt / \left[\pi (vt)^2 h \right] = Q / \left(\pi h v^2 t \right)$$

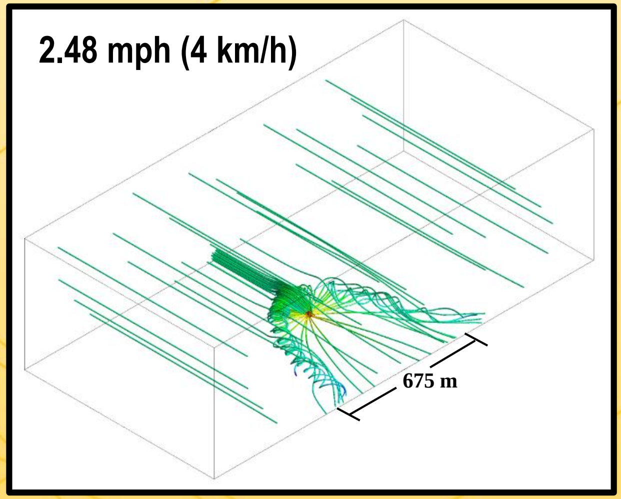


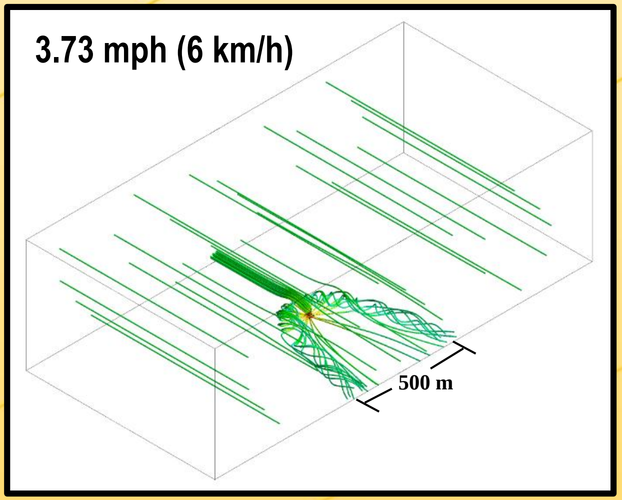
✓ If we double the flowrate, both Q and v are doubled, so clean air concentration decreases and $PM_{2.5}$ concentration increases.

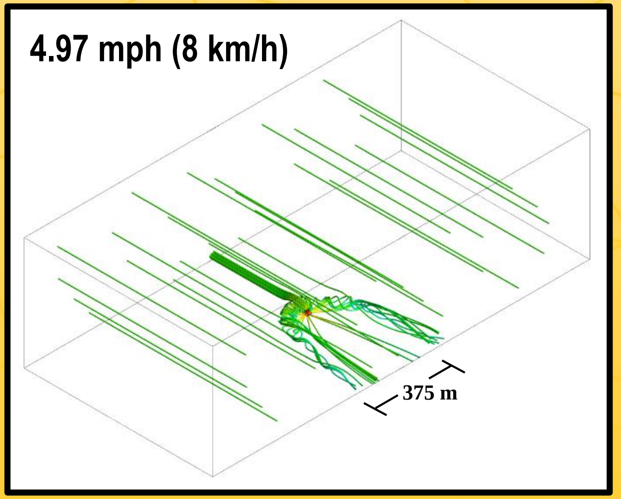
AMSA under Uniform Ambient Wind Speeds

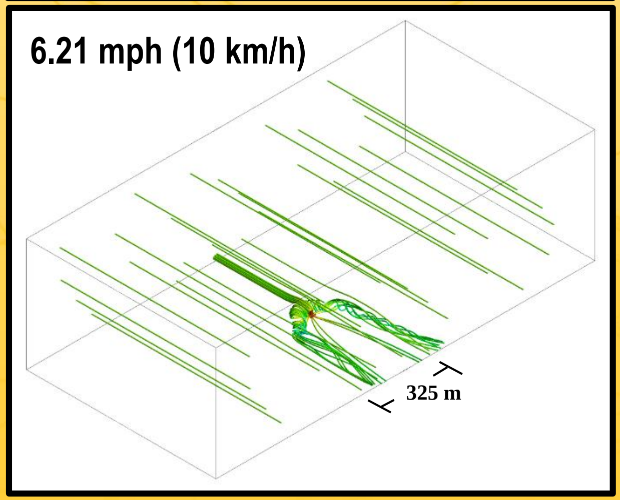
- Streamlines colored by velocity at system flowrate of 2000 m^3/s.











- Downstream vortex are generated.
- It expands as wind speed decreases.

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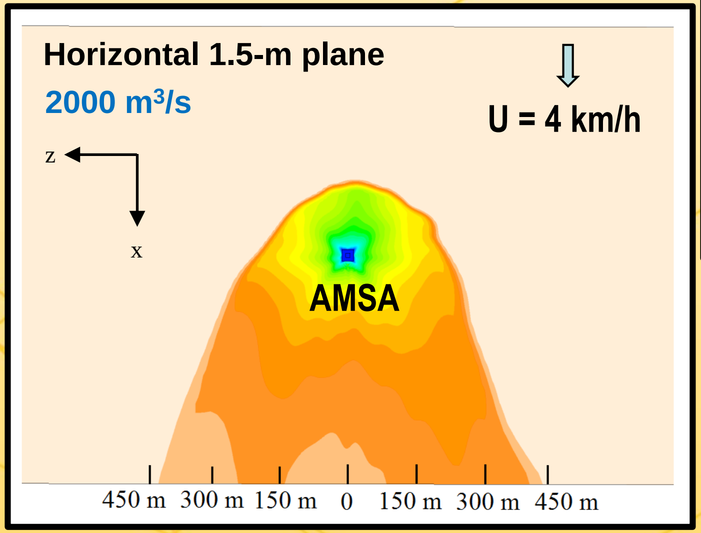
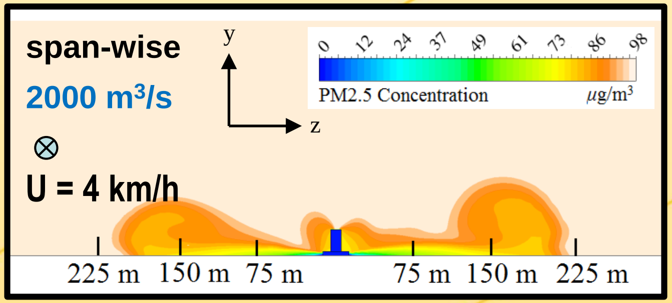
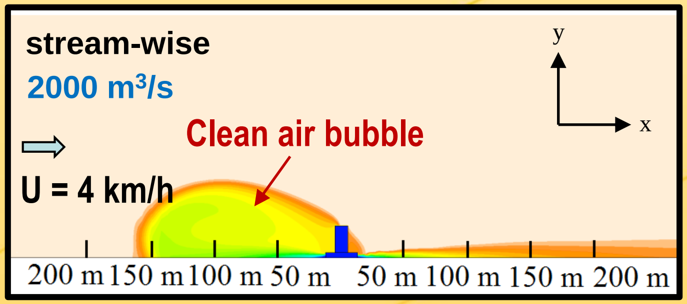
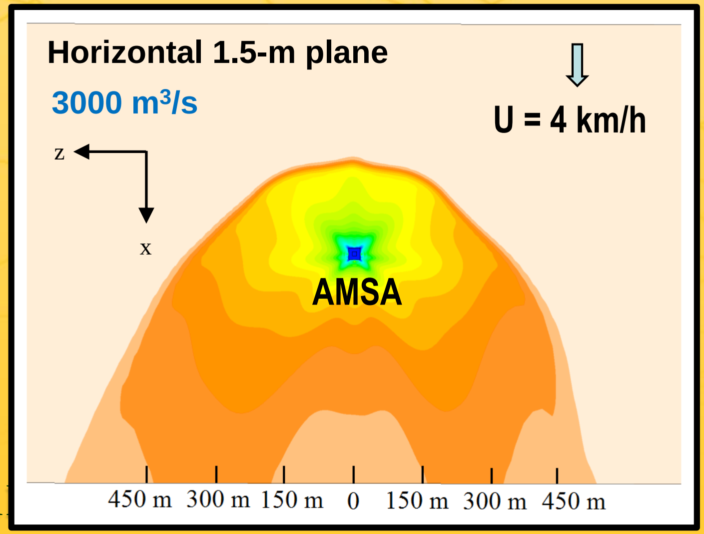
$PM_{2.5}$ Concentration Contours under Ambient Wind Speed of 4 km/h

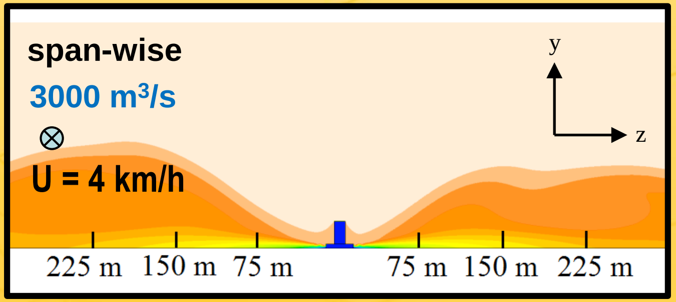
- Contours of $PM_{2.5}$ concentration at ambient wind speed of 2.48 mph (4km/h).
- Clean air bubble appears at upstream of AMSA.
- A higher flowrate gives a larger cleaning area.
- But local $PM_{2.5}$ concentration may not be lower.

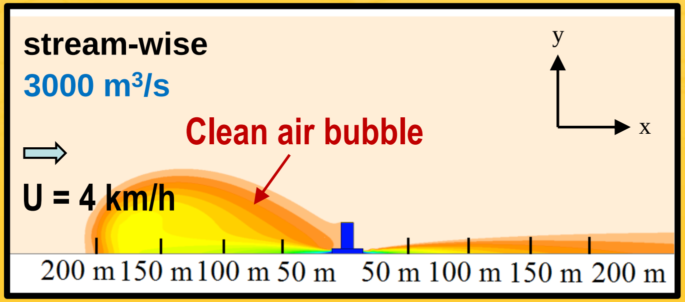






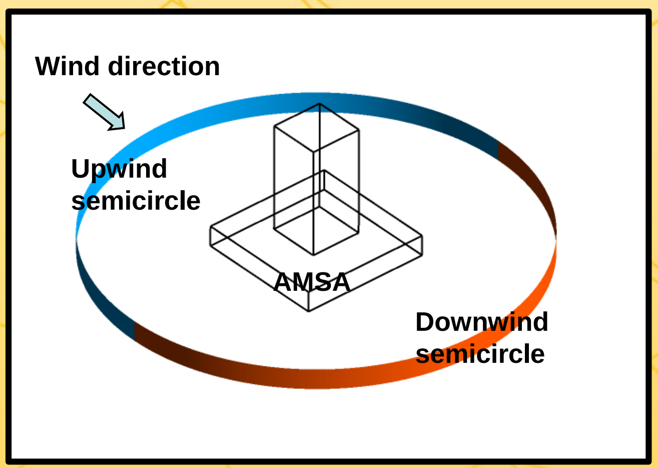


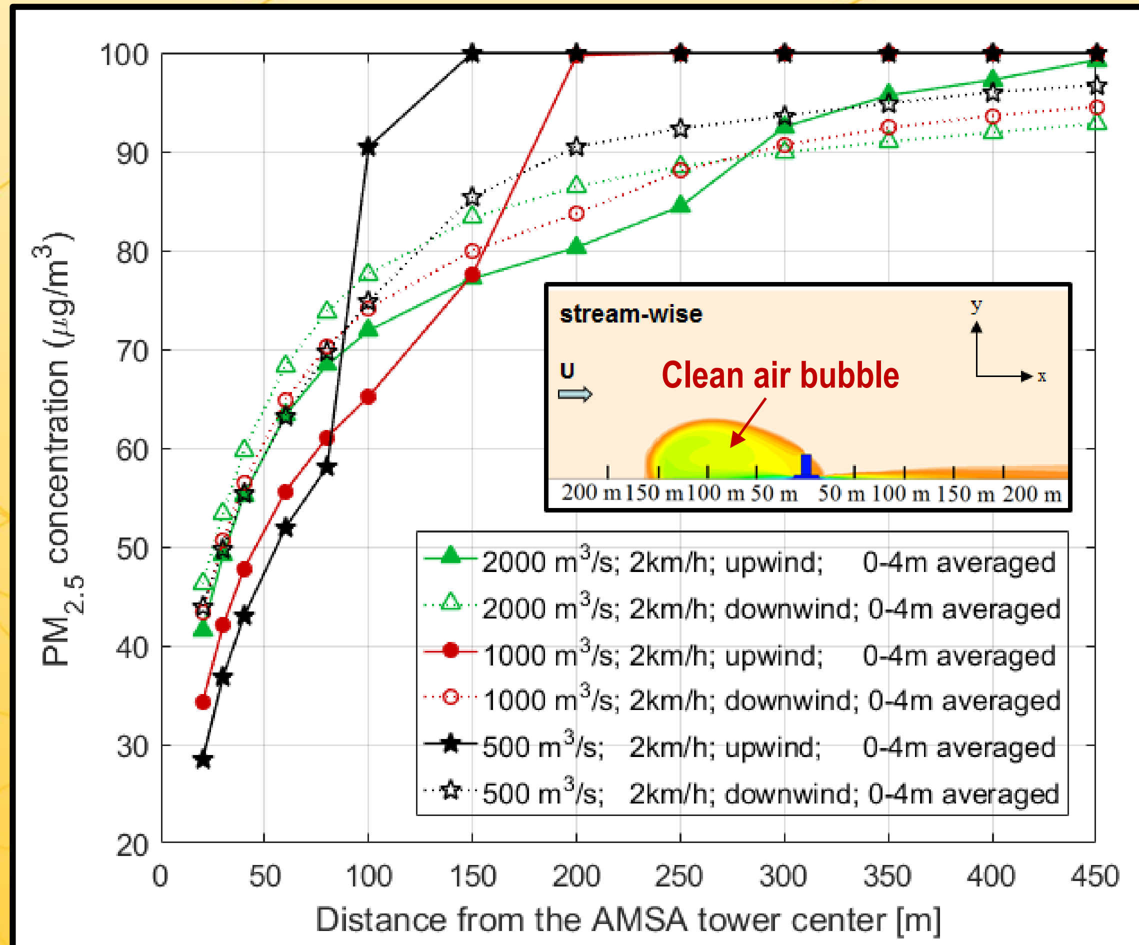




Effect of System Flowrate on $PM_{2.5}$ Concentration with Wind Speed of 2 km/h

- Figure showing the effect of flowrate on $PM_{2.5}$ concentration at a uniform wind speed of 2 km/h.

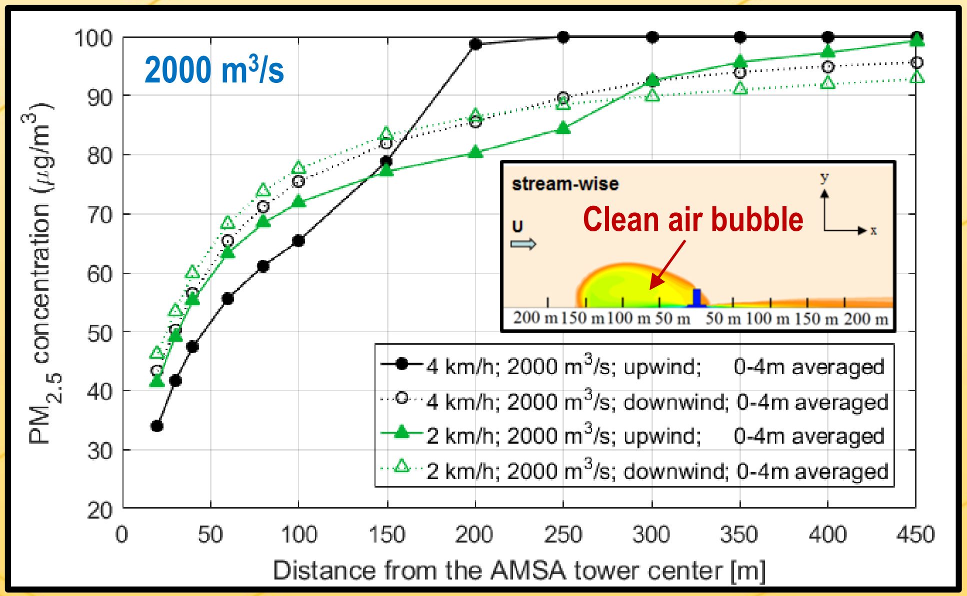


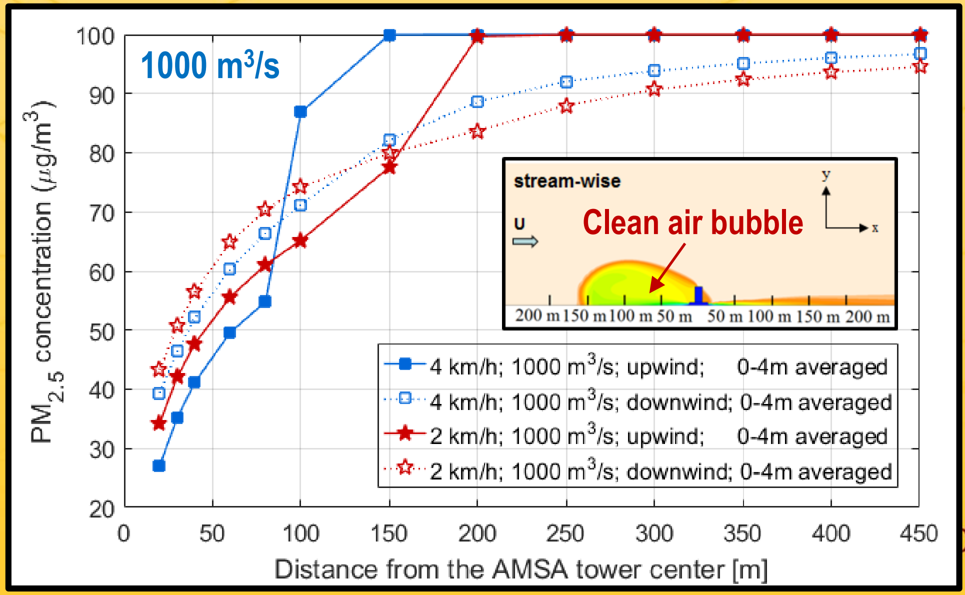


- Upwind: sharper concentration gradient between 75 - 200 m indicating the edge of clean air bubble.
- Downwind: smoother concentration gradient.
- As flowrate decreases, $PM_{2.5}$ concentration becomes lower close to AMSA, and higher at the locations far away.

Effect of Ambient Wind Speeds on $PM_{2.5}$ Concentration Profiles

- Figure showing the effect of ambient velocity on $PM_{2.5}$ concentration at two flowrates.
- As ambient velocity increases, the upwind clean air bubble has a smaller volume, but the $PM_{2.5}$ concentration is lower close to AMSA.
- At downwind location, a higher ambient velocity also decreases the $PM_{2.5}$ concentration close to AMSA, but far away from AMSA, the concentration becomes higher.
- In general, the upwind location is cleaner than the downwind, because of the accumulation of clean air inside the upwind bubble.





Summary

- Numerical simulations have been conducted to study the $PM_{2.5}$ concentration profiles of AMSA under different ambient conditions.
- A higher system flowrate benefits a larger area but doesn't decrease the local $PM_{2.5}$ concentration significantly.
- Under a quiescent atmosphere, a lower system flowrate gives lower $PM_{2.5}$ concentration.
- With uniform ambient wind speeds, a clean air bubble is generated at the upwind location, contributing to a lower $PM_{2.5}$ concentration than the downwind.
- At a constant system flowrate, a lower clean air flow velocity helps to achieve a lower local $PM_{2.5}$ concentration.
- Under real urban conditions, the $PM_{2.5}$ concentration profile results may be different.

Future Work

- To study $PM_{2.5}$ concentration profiles under real urban conditions.

Thank You