Validation of CFD for the Flow Around a Computer Simulated Person in a Mixing Ventilated Room

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Overview

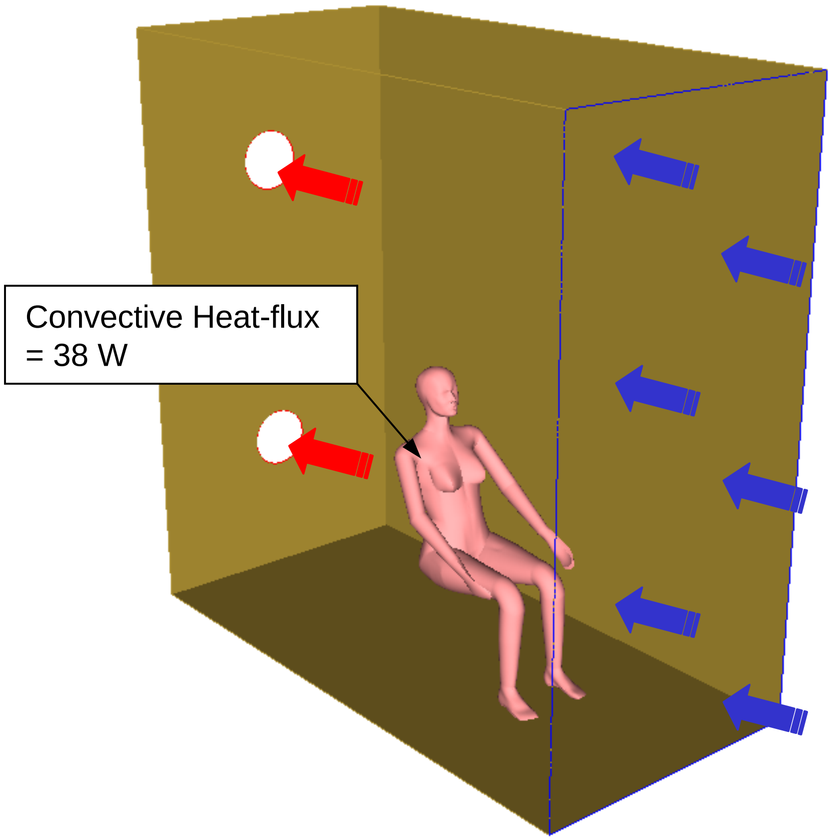
- Personal Micro-Environment (PME) involves complex geometry and many complex fluid dynamics phenomena (low Re flow, thermal buoyancy, PM behavior)
- To better design the personal indoor environment, detailed studies using state-of-the-art measurement and modeling techniques are necessary to tackle these difficult issues
- As a result two concerns need to be addressed:
  1. *Validation of existing airflow, turbulence, PM transport, etc. models*
  2. *Modify existing or develop new models where necessary*

Motivation and Objectives

- Investigate performance of CFD and verify what needs to be done to improve them – validation needed
- Benchmark cases are needed for proper validation
- Important parts:
  1. *Grid Study*
     - Number of cells required for grid independence
     - Resolve the boundary layer
     - Topologies
  2. *Turbulence Models*
     - Typical RANS models (standard k-ε)
     - New RANS models (v^2-f)
     - Validate with existing experimental data
  3. *Boundary Conditions*
     - Inlet/outlet conditions (velocities, turbulence, concentrations)
     - Wall conditions (temperature/heat-flux, particulate matter)

Mixing Ventilation

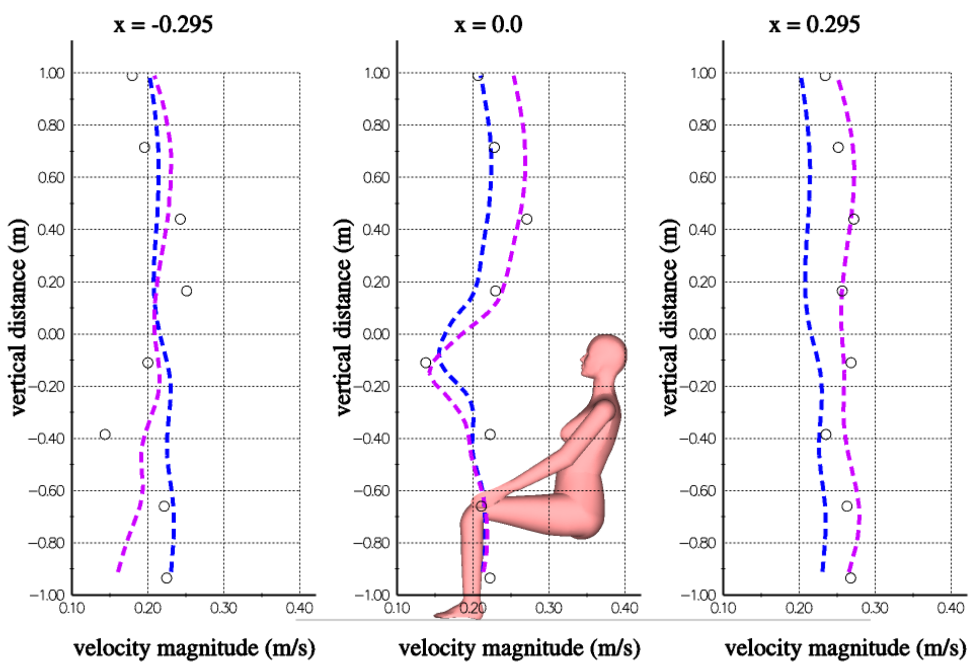
- Approximated from recirculating flow
- Steady-state, uniform 0.2 m/s inlet, TI = 40%, l = 0.5 m
- Test data – velocity magnitude



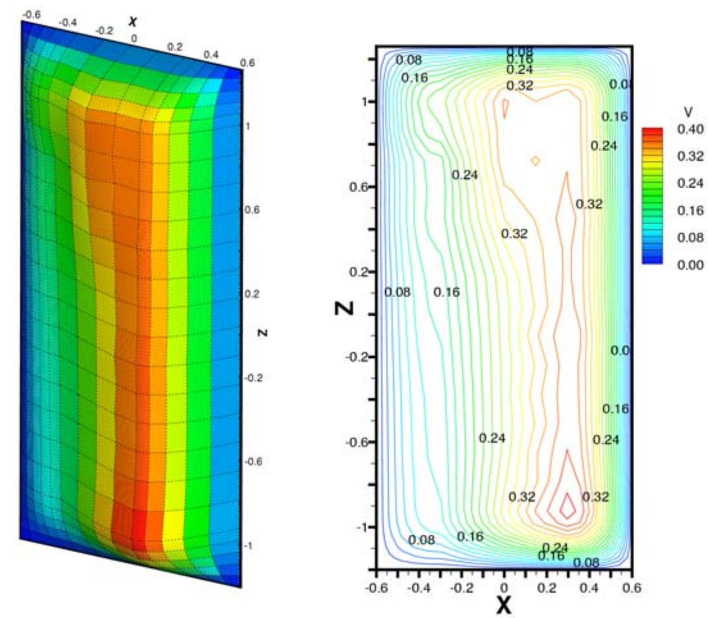
Seated Thermal Mannequin in **Mixing Type** Ventilation

Inlet Boundary

- In general, CFD results in the far-field flow compare to data well
- Care must be exercised when taking data
- Non-uniform velocity inlet profile re-constructed using data



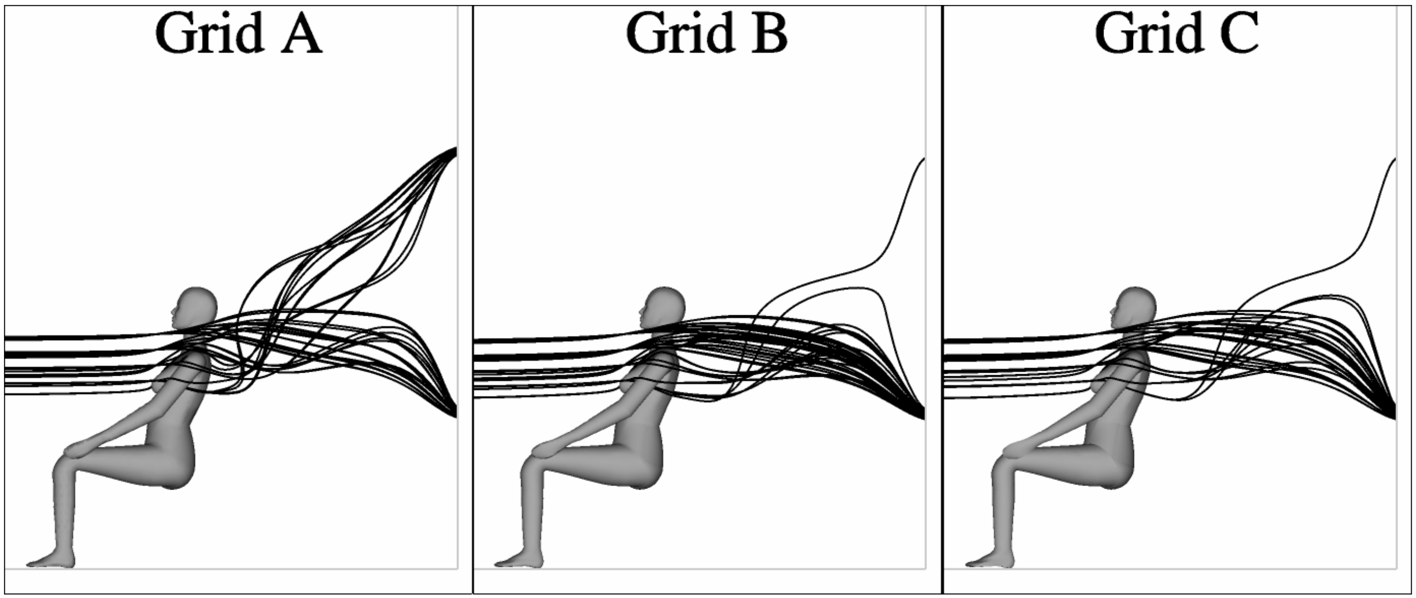
Velocity Magnitude Behind Manikin: **blue – uniform inlet**; **purple – non-uniform inlet**; **circles - data**



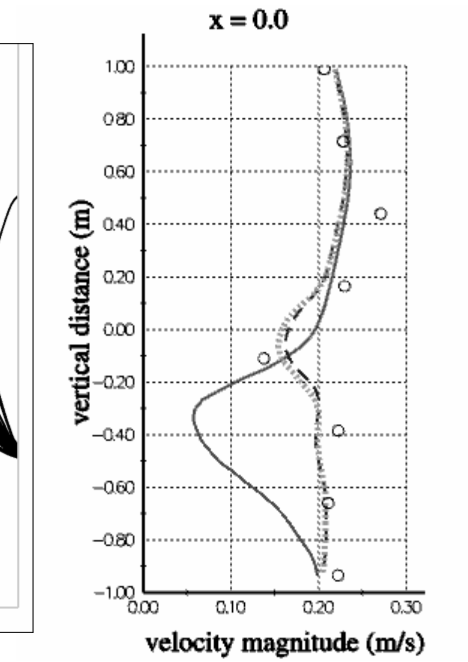
Reconstructed Inlet Profile

Grid Dependency

- Grid independence achieved with 2-3 million cells - including BL grid near manikin
- Wake behind manikin not resolved with Grid A (1.2 million)



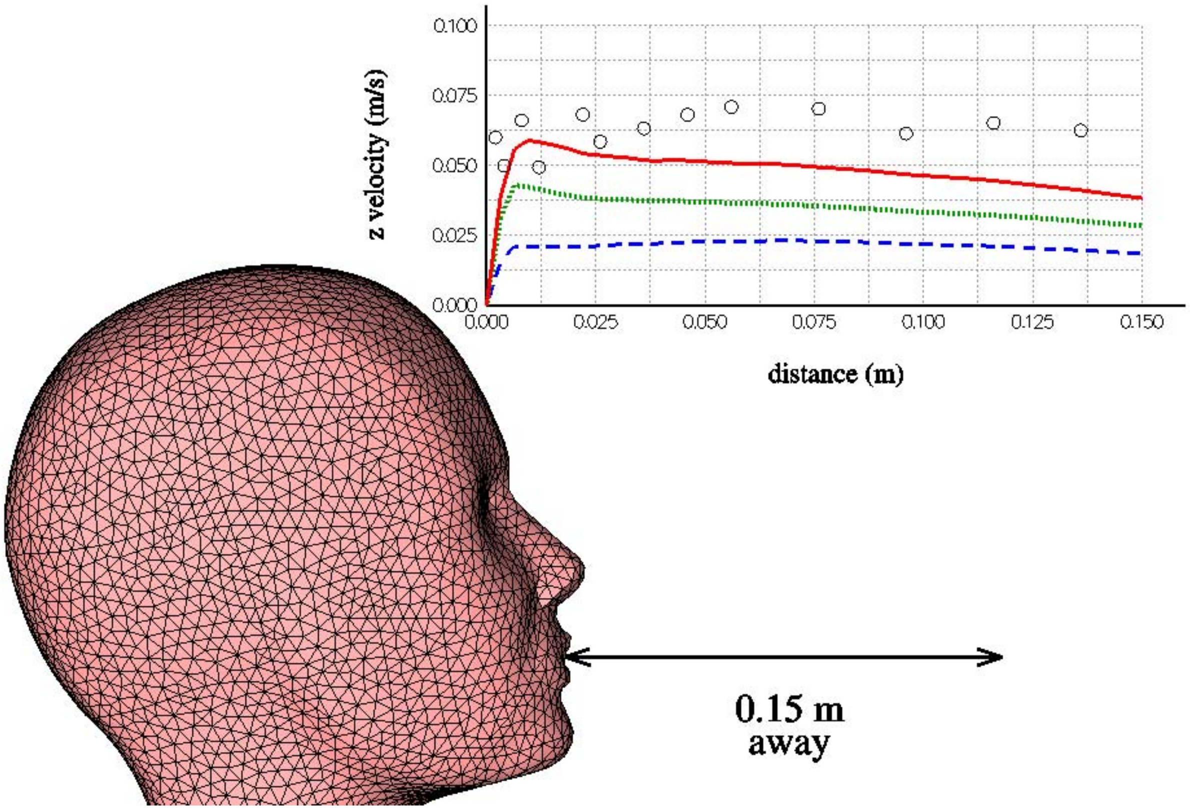
Grid Dependency: Streamlines from Shoulder



Velocity Mag.
Behind Manikin

Turbulence Model

- Velocity away from manikin not sensitive to turbulence model
- More variations between models near the manikin surface – v^2-*f* matches best with data

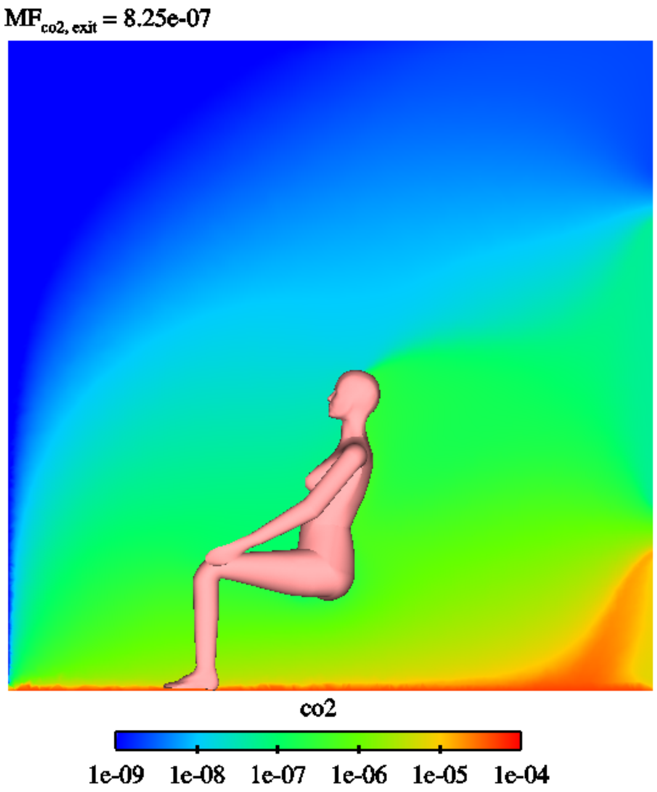


Vertical Velocity Near Manikin Mouth: **solid – v^2-f; dashed – standard k-ε; dotted – low Re k-ε; circles - data**

Gaseous Pollutant

- “Mixing” ventilation is not fully mixed – significant gradients in concentration still exist
- Concentration ratio is far from unity (“perfectly” mixed): 1-2 orders magnitude lower in the breathing zone
- Boundary layer resolution near floor affect the mass-flux; therefore exit concentrations differ

CO_2 Concentration:
50ppm source at floor



Summary

- More information needed at inlet plane (velocity components and turbulence quantities)
- Higher fidelity data throughout flow-field needed
- Grid resolution around and on manikin important – care must be taken
- v^2-f best overall RANS turbulence model
- Characterizes a mixing ventilation scenario