Simplified Physical and Simulation Modeling of Building Occupants

A seminar in "Experimental and CFD Benchmark Studies of Indoor Flow around Thermal Manikins"
ASHRAE 2006 winter meeting, Chicago

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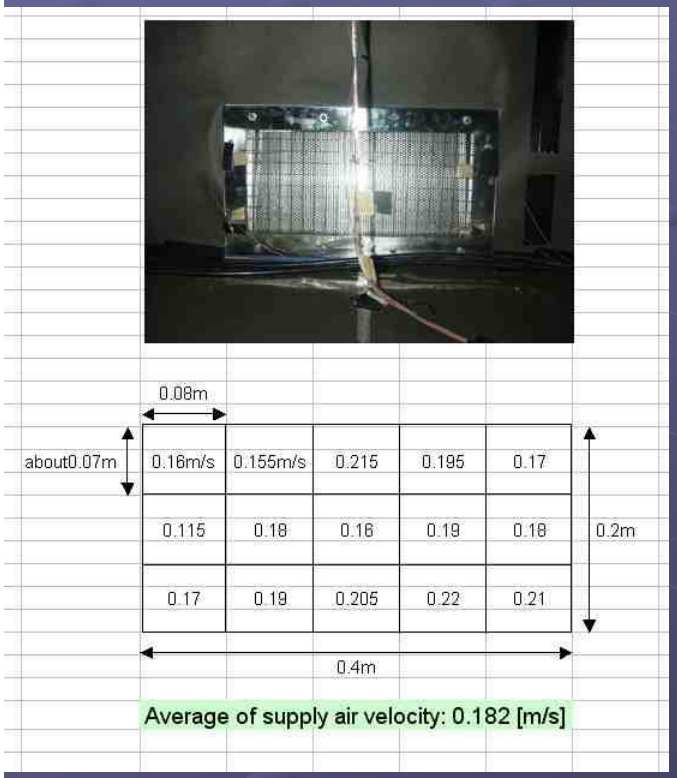
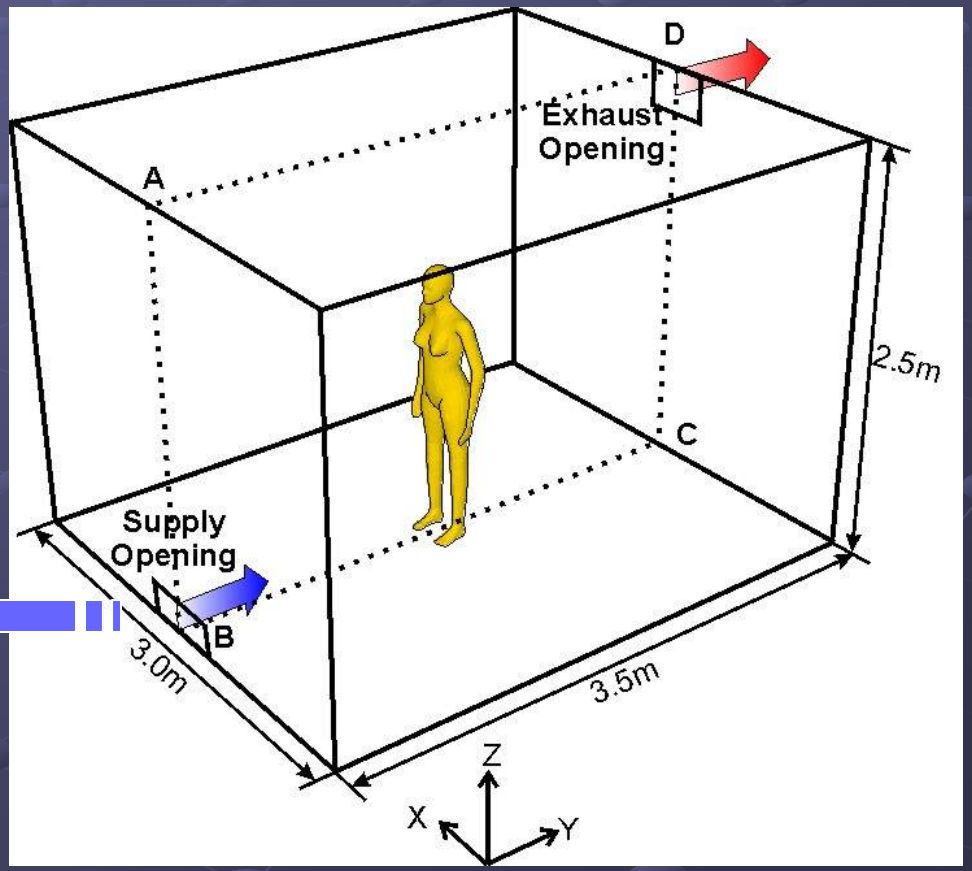
Outline

- Background
- Heat flux ratio for human simulator
- Grid (in)dependence
- Results and discussion
- Heat transfer coefficients
- Conclusions
- Future work

Background

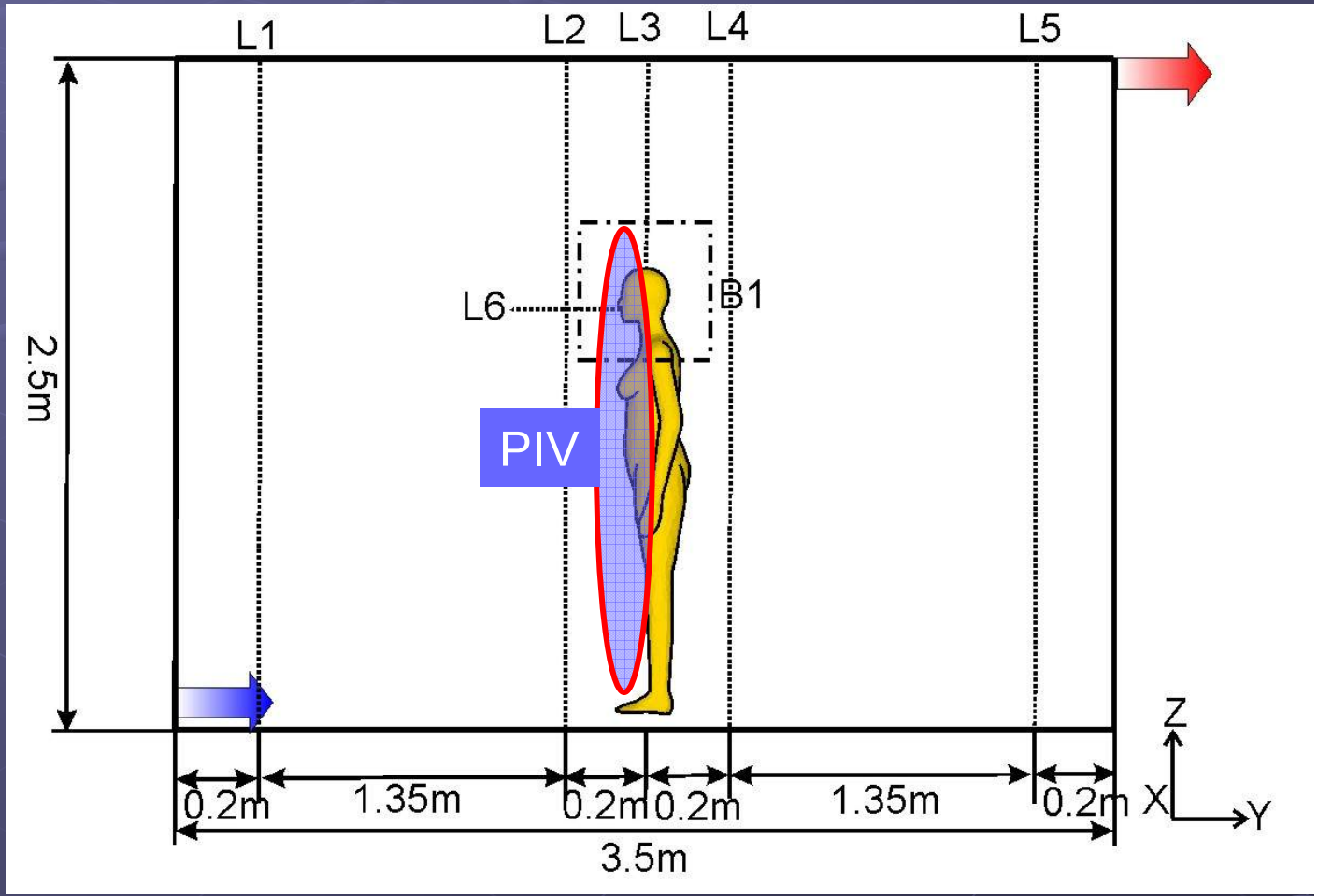
- Kato laboratory, University of Tokyo
  http://www.cfd-benchmarks.com
- Benchmark Tests for a Computer Simulated Person (Nielsen et al. 2003)





Measuring Poles

- Temperature and velocity (L1, L2, L4, L5)
- PIV (~ L3)



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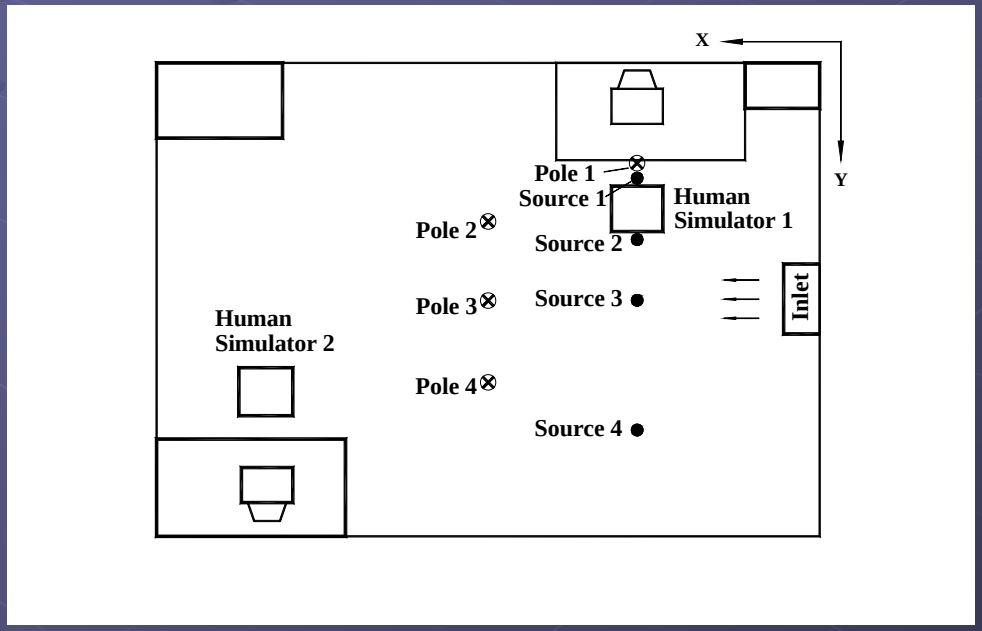
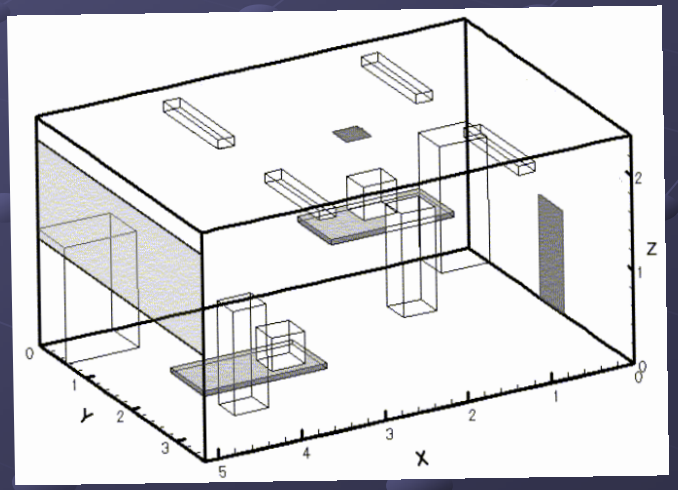
Heat Flux Ratio for Human Simulators

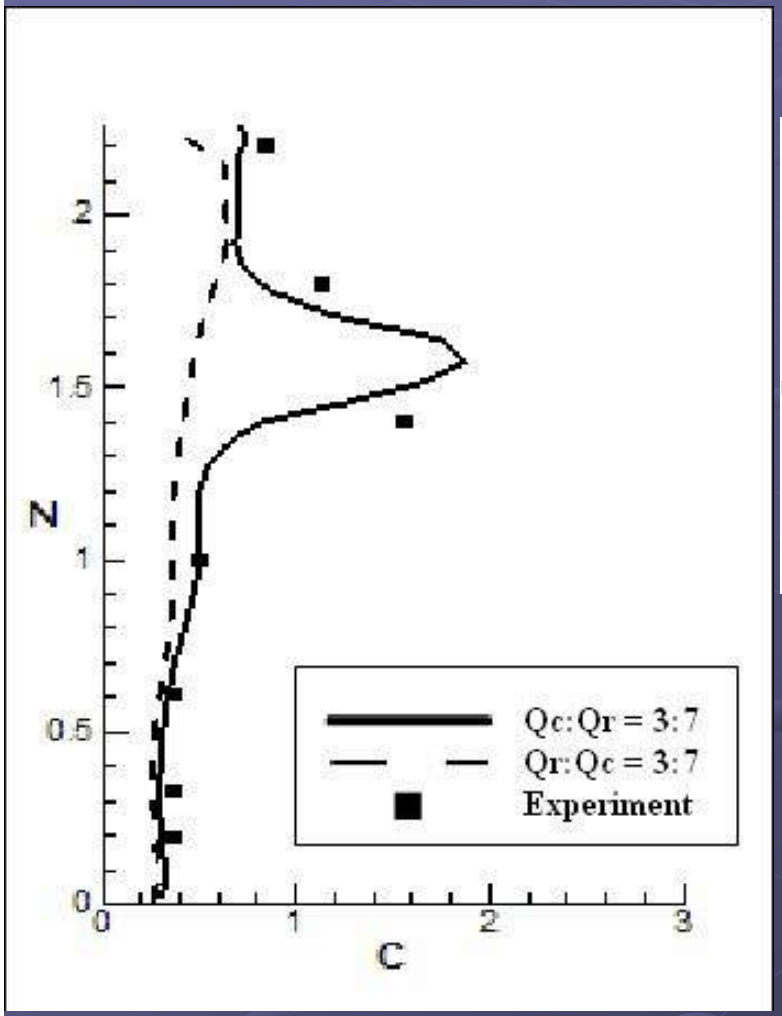
- Critical Simulation Parameters for Accurate CFD Predictions of Contaminant Dispersion from Indoor Point Sources (Hu et al. 2005)

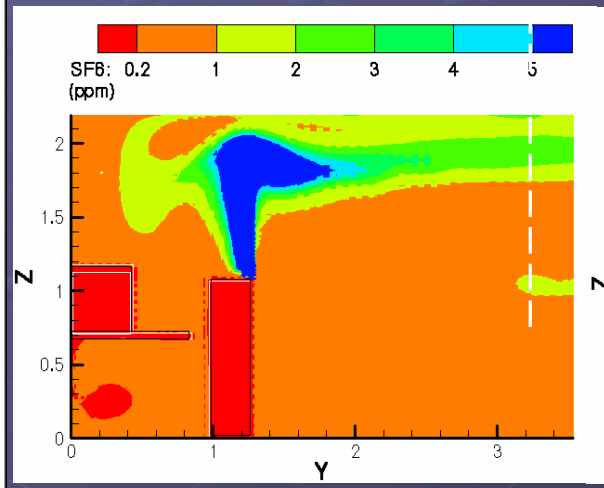




Thermal: Simulation Results

- Convection vs. Radiation (Qc:Qr)





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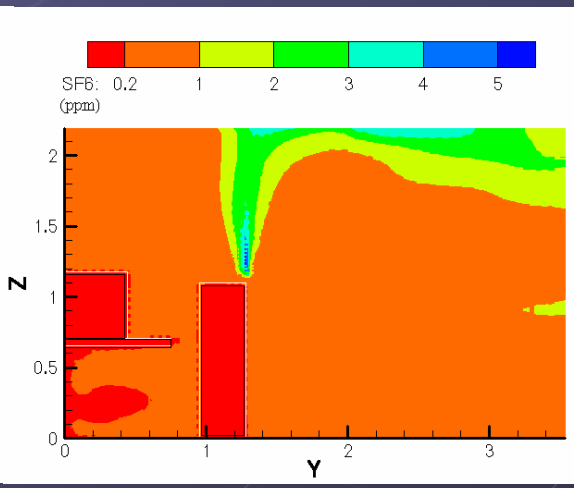

Qc:Qr=7:3

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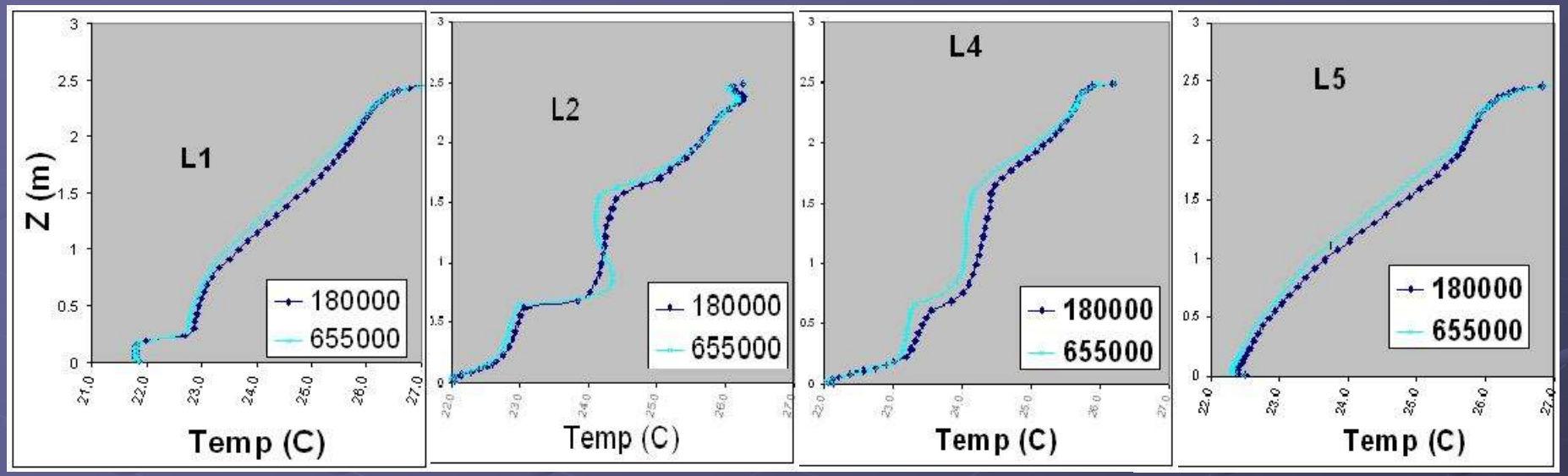
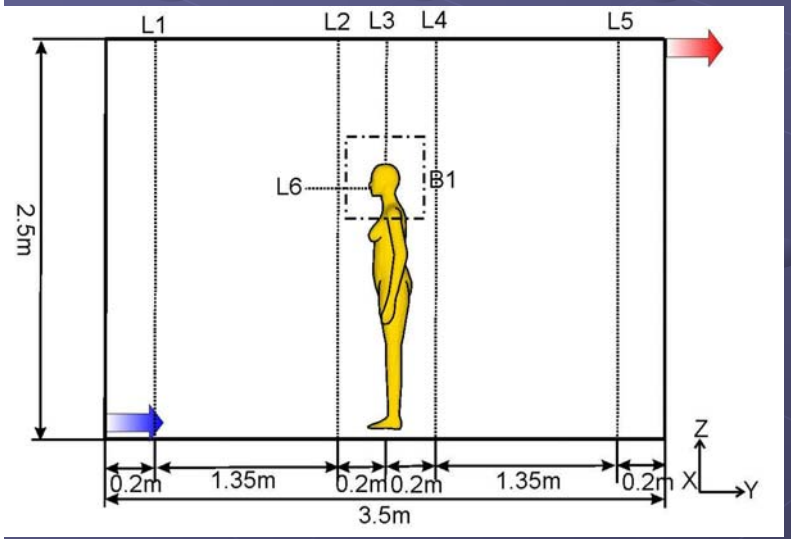
Grid (in)dependence - Temperature

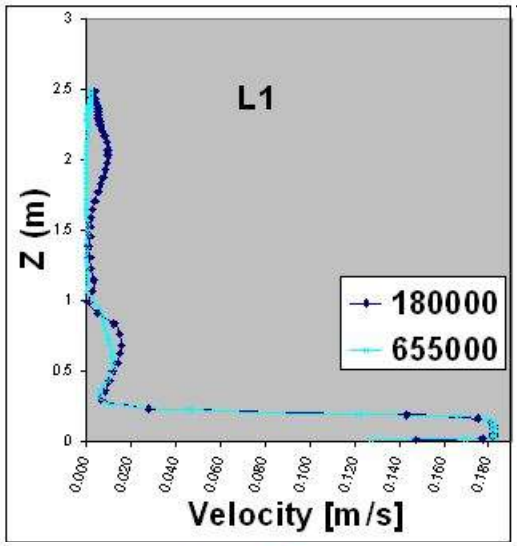


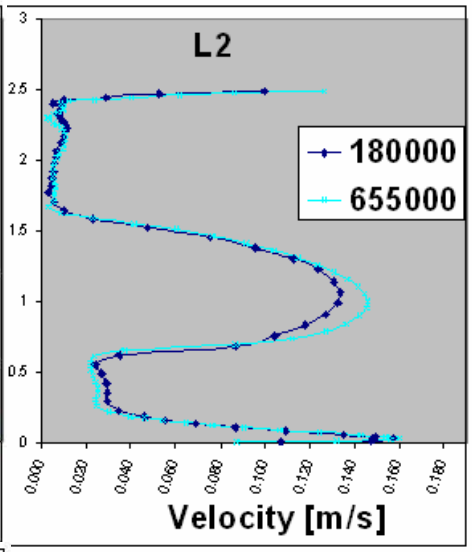


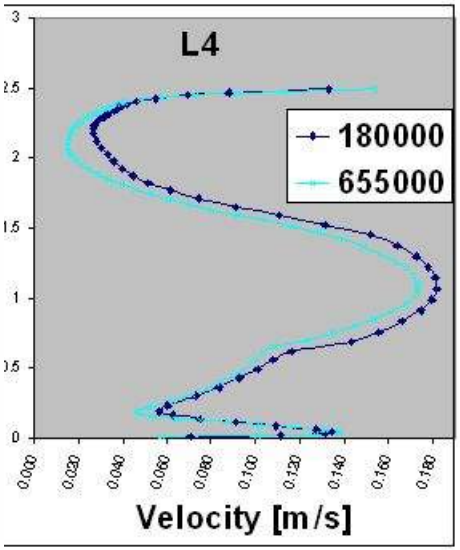
On 2.4GHz Pentium 4, 1GB RAM and 20,000 iterations

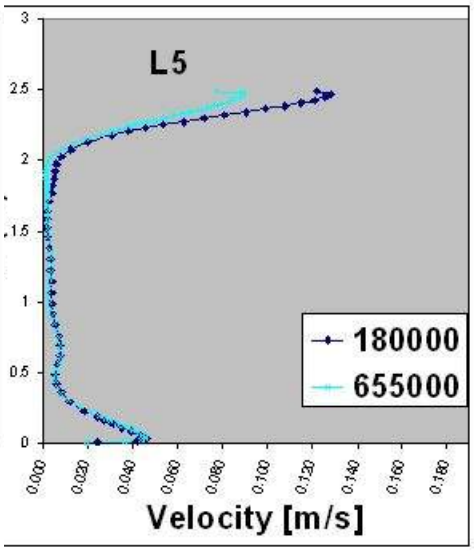
- 180,000 cells → 26h computations
- 655,000 cells → 84h computations

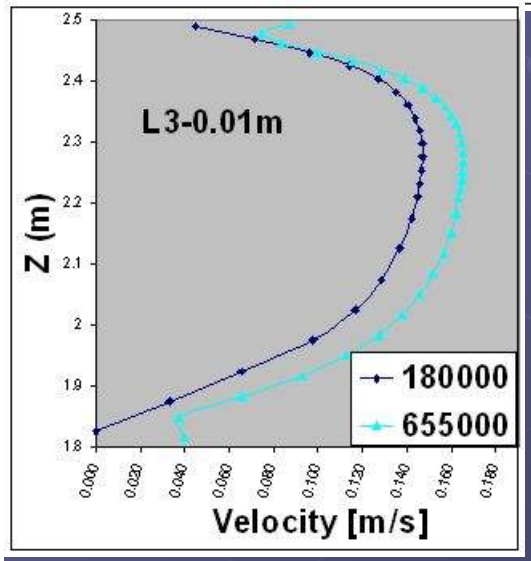
Grid (in)dependence - Velocity

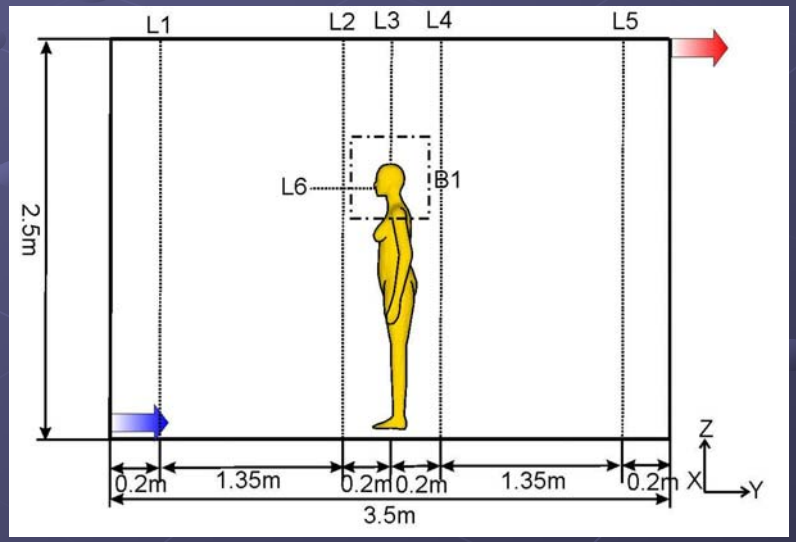












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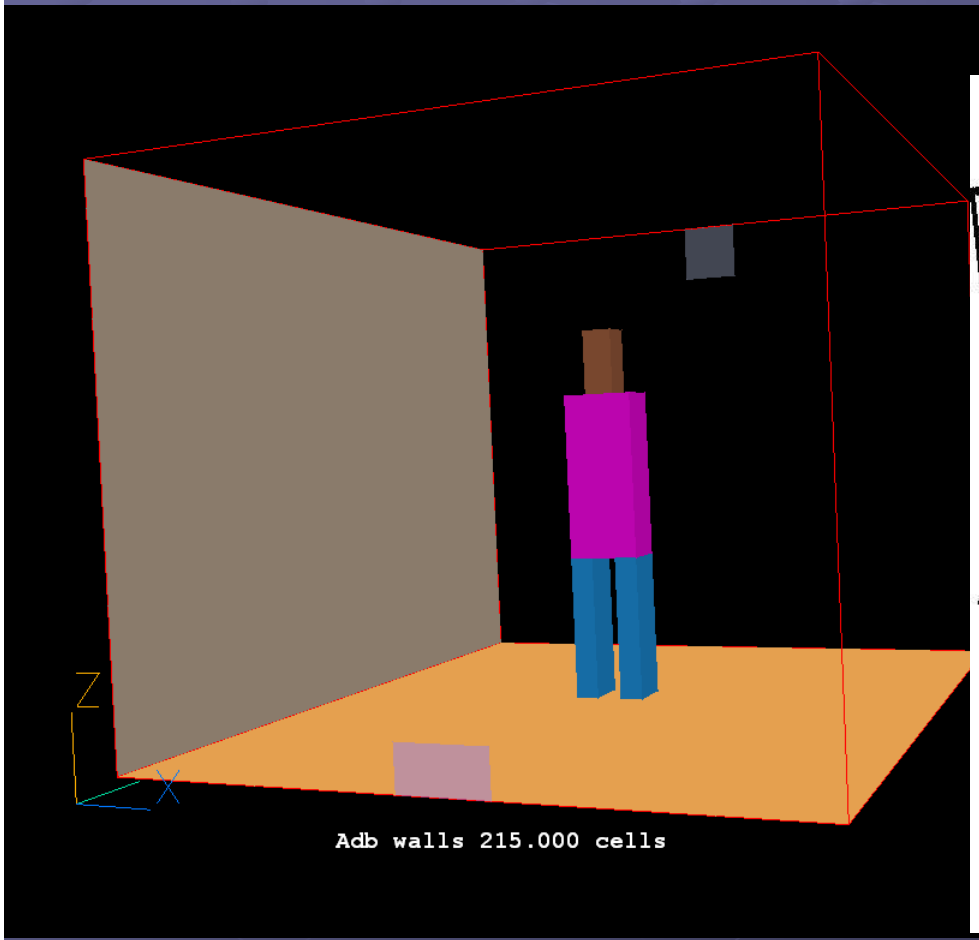
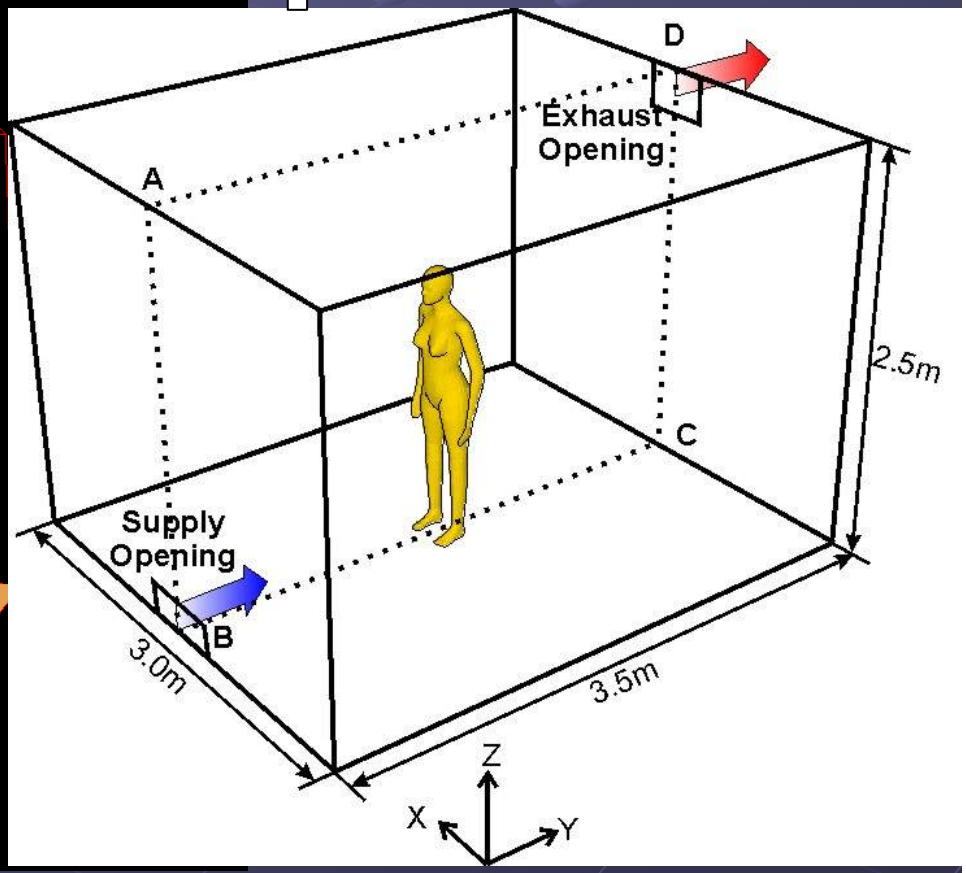
Simulation Model

- Simplified human manikin simulations

Compare to





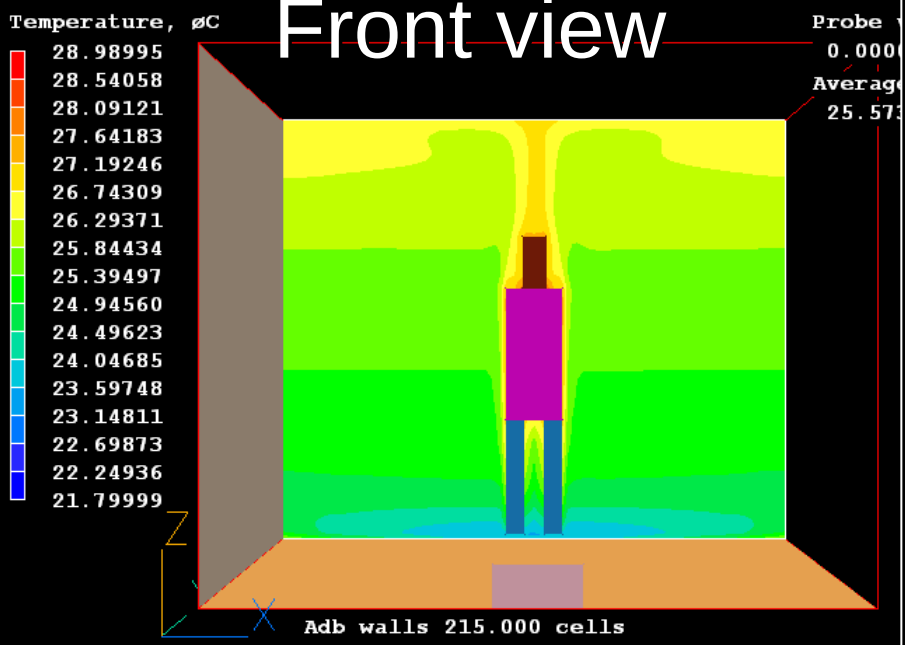
Simulation Data

- Total Heat Flux = 76 W
- Manikin Heat Flux = 22.8 W
- Radiation Heat Flux = 53.2 W + ? (through "adiabatic" walls)
- Simulation Domain:

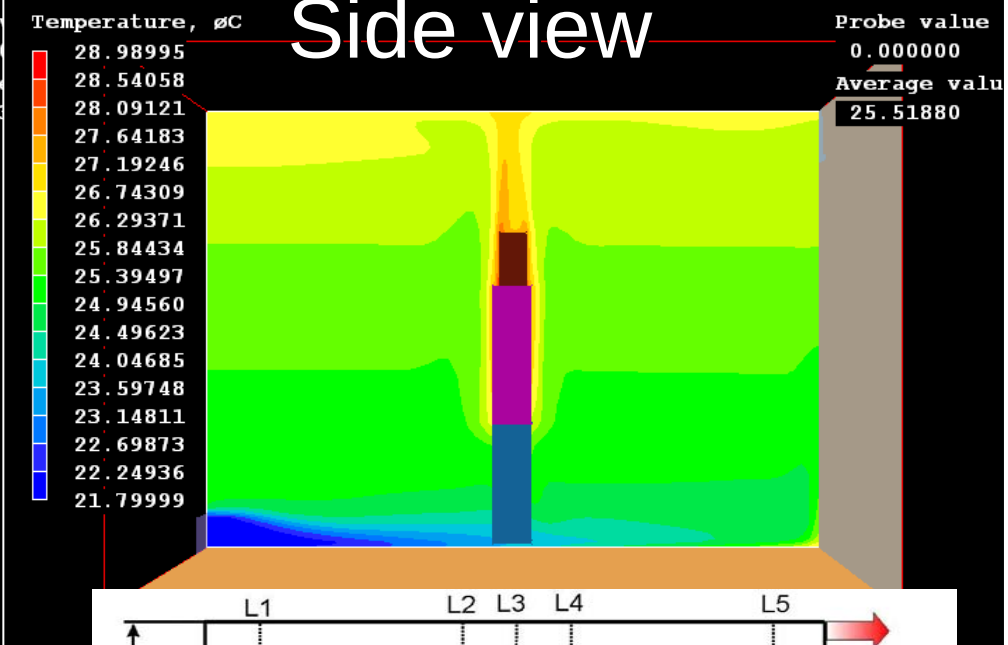
  X x Y x Z = 56 x 62 x 62 ≅ 215,000 cells
- k-ε turbulence simulation model
- 20,000 iterations
- PHOENICS 3.6.1 CFD simulation software

Temperature Results

Front view



Side view



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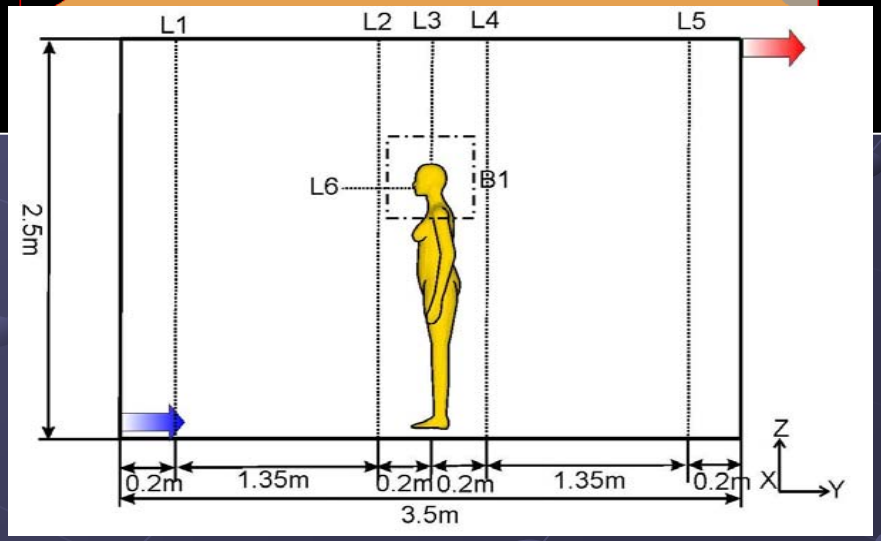
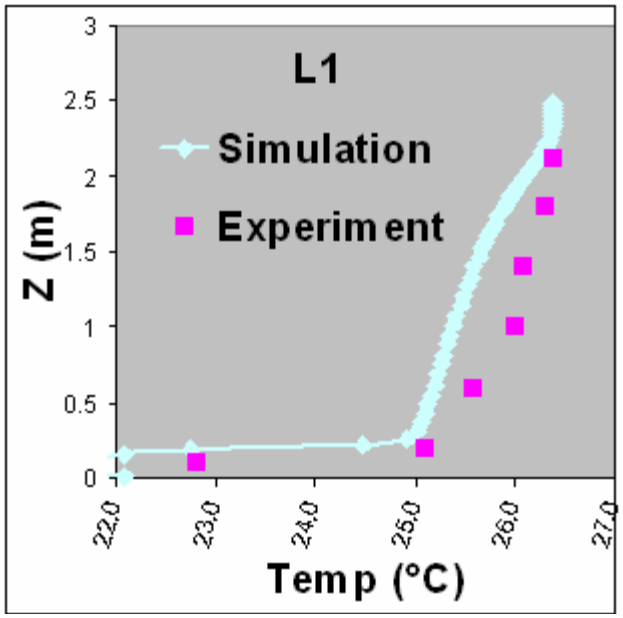
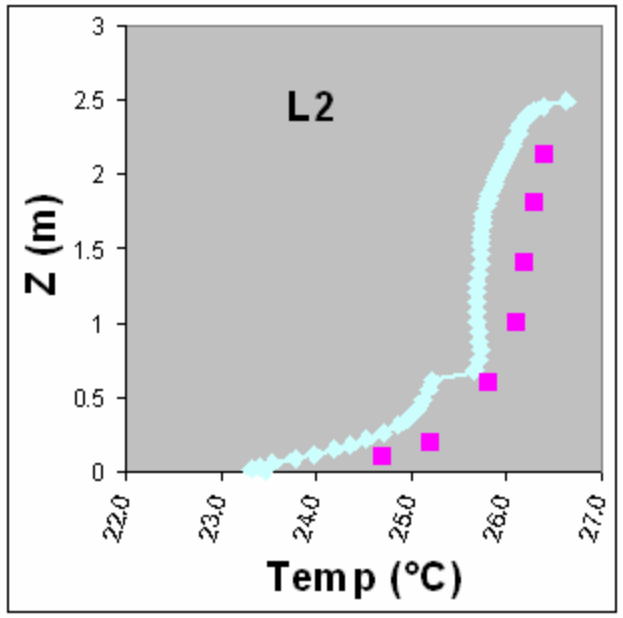
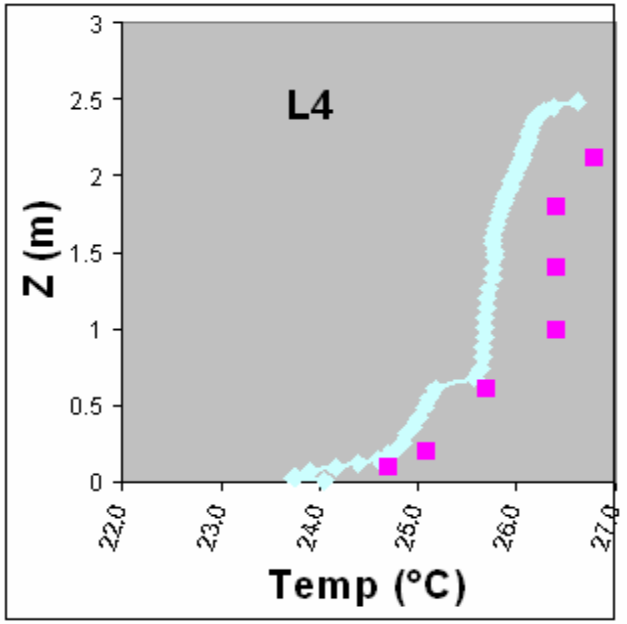
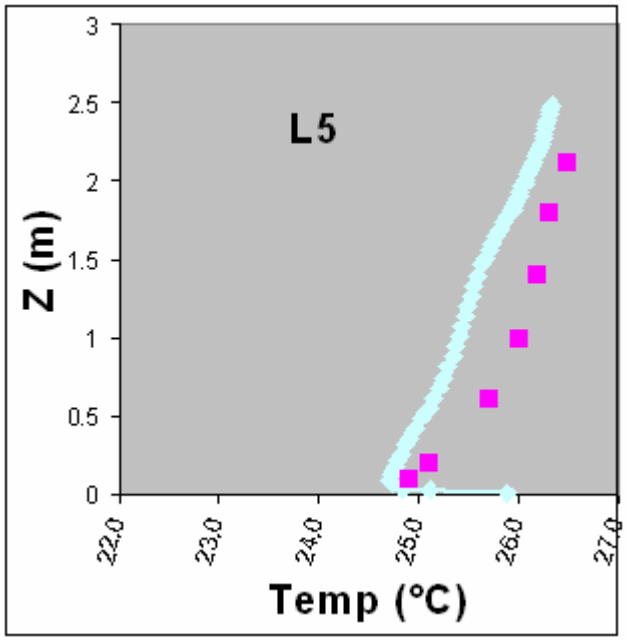


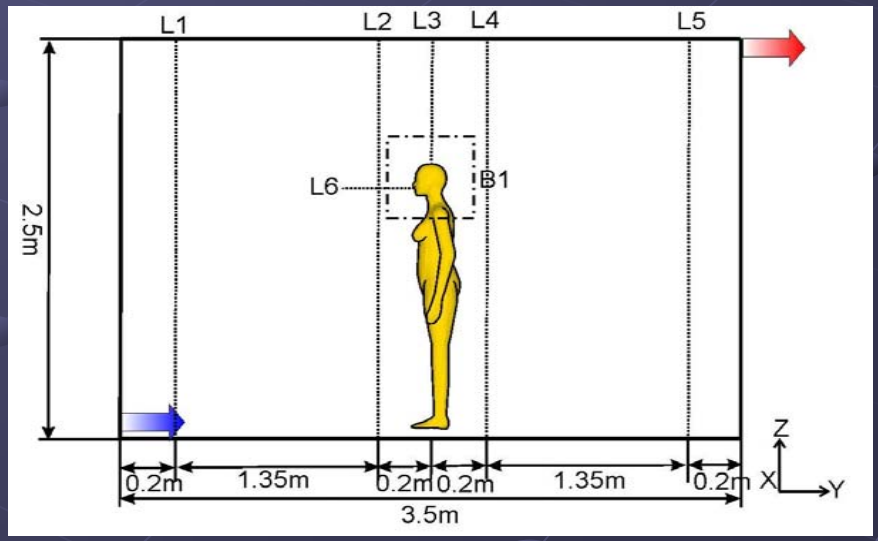
Temperature Results



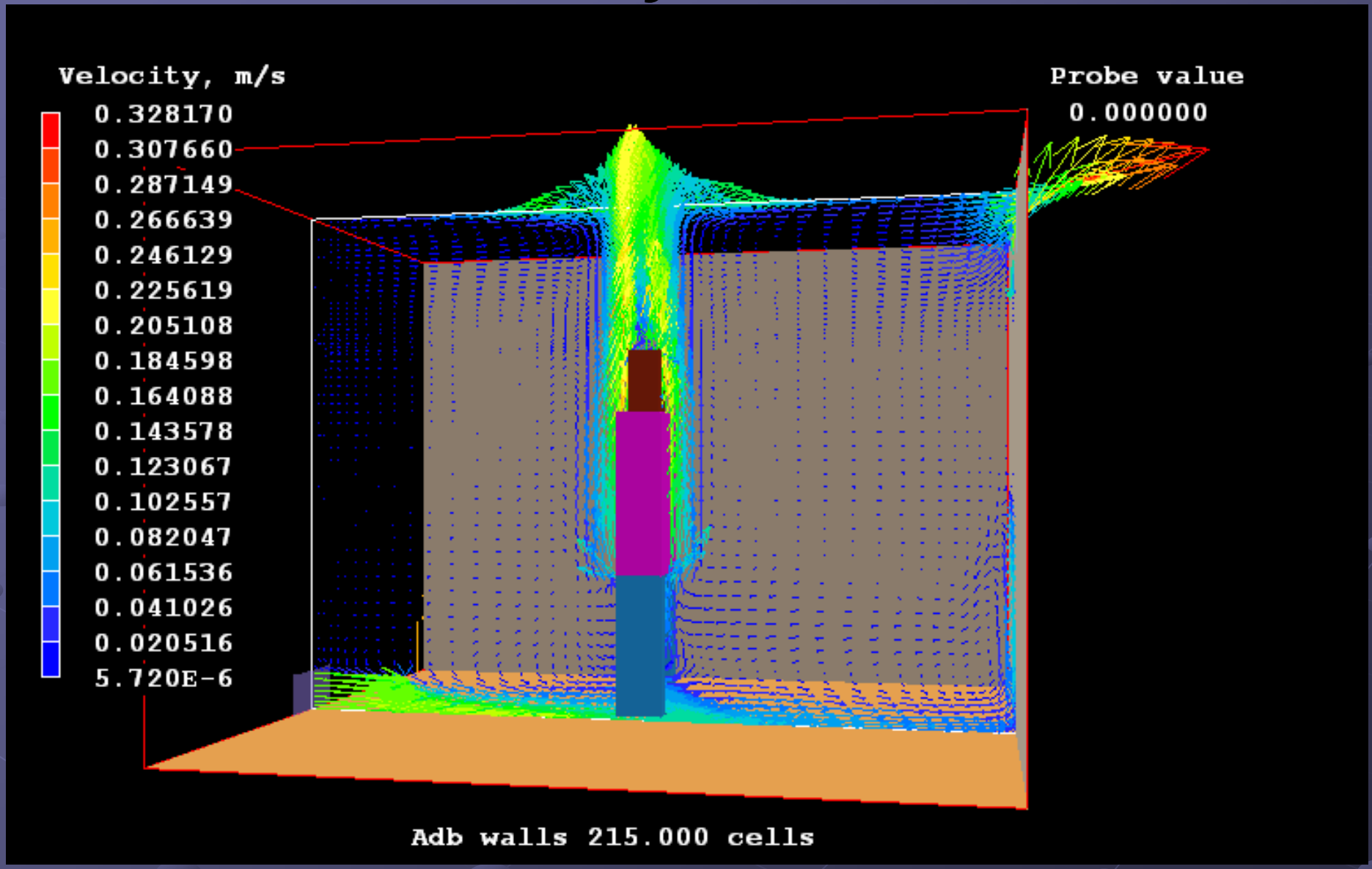








Velocity Results



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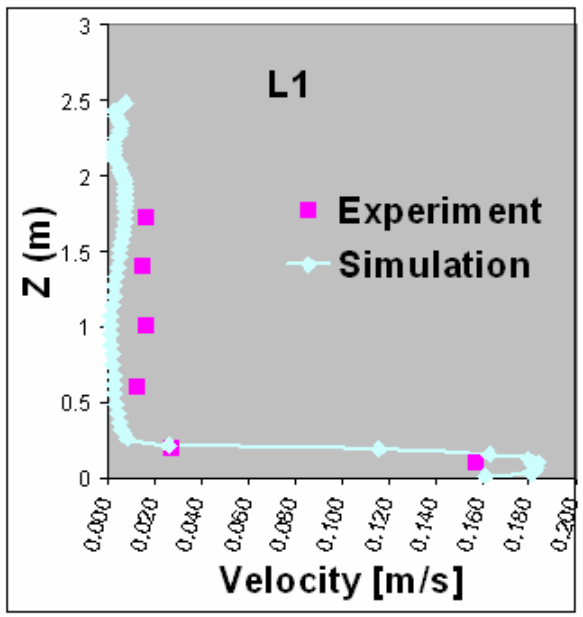
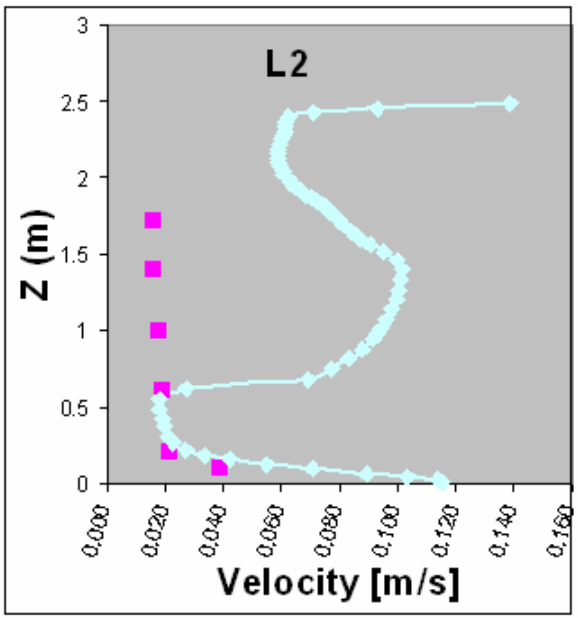
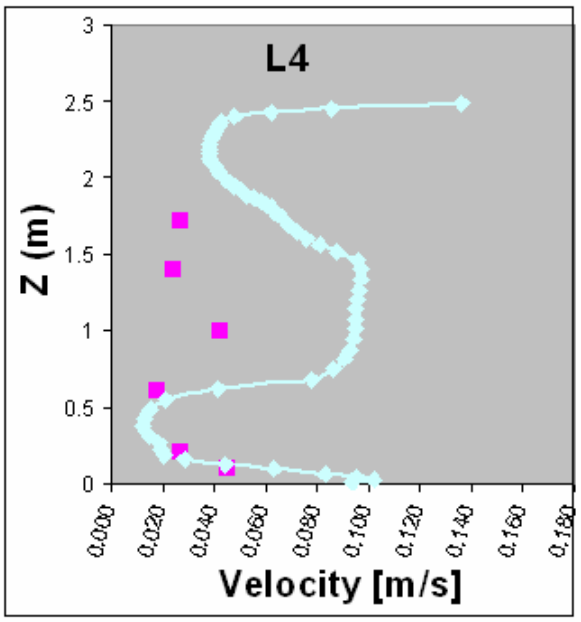
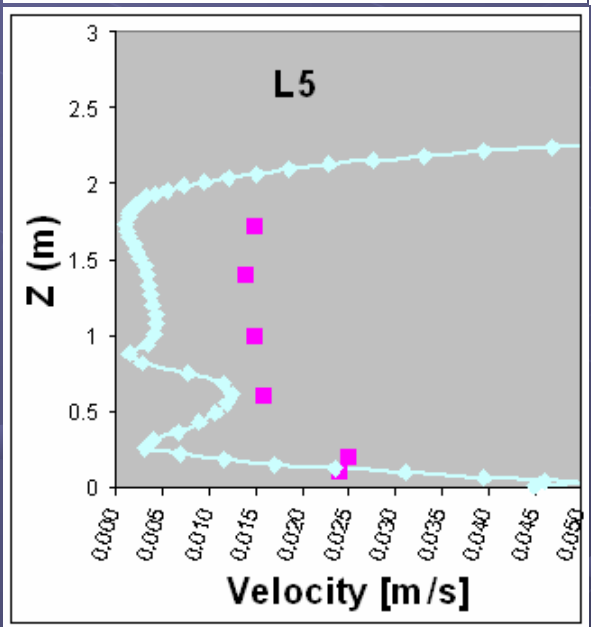
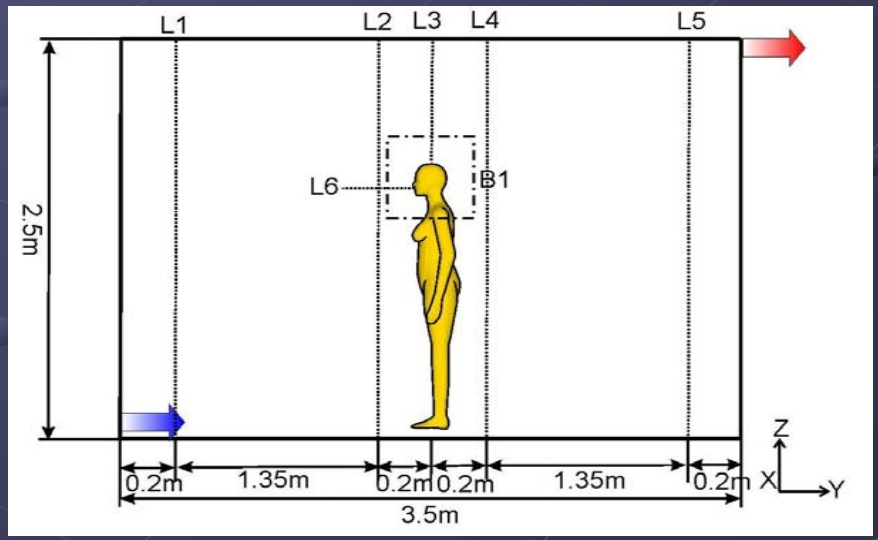






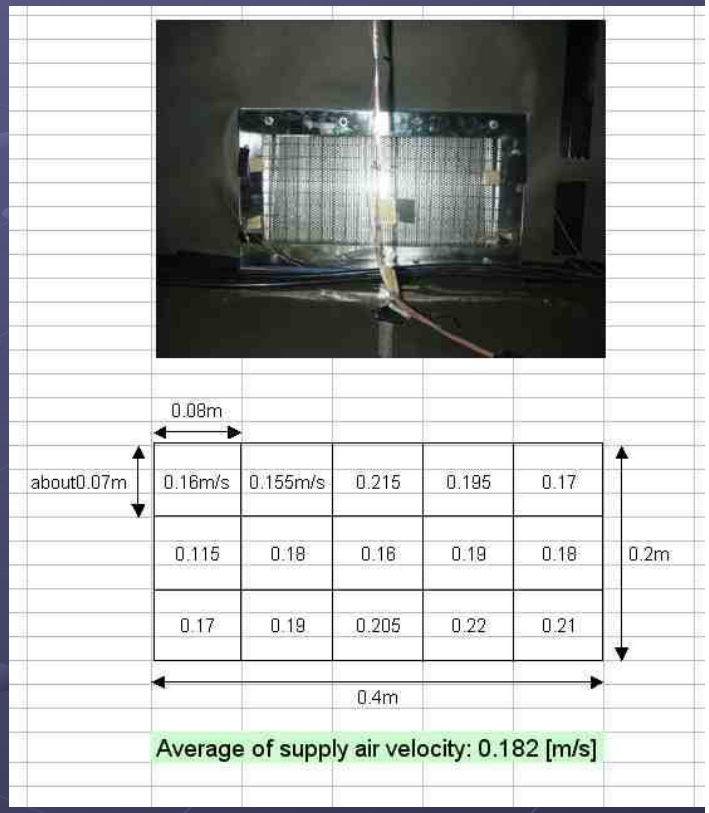




Discussion

- Diffuser boundary conditions
  - Flow rate measurements
  - Diffuser design – geometry
- Thermal boundary conditions
  - “Adiabatic” wall temperatures

  ⇒ Heat transfer coefficients



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Heat Transfer Coefficients

- Convection coefficient $h = \left| \frac{q_{convective}}{T_{surface} - T_{air}} \right|$

(Awbi and Hatton 1999; Novoselac et al. 2005)

Recommended convection correlations h for a room with displacement ventilation

Surface	Regime	Convection correlation
Floor	$T_s > T_{air}$	$\left[\left(2.175 \cdot \Delta T^{0.308} / D_h^{0.076} \right)^6 + \left(\lvert T_s - T_{supply} \rvert / \Delta T \cdot 0.48 \cdot ACH^{0.8} \right)^6 \right]^{1/6}$
	$T_s < T_{air}$	$\left[\left(0.704 \cdot \Delta T^{0.133} / D_h^{0.601} \right)^6 + \left(\lvert T_s - T_{supply} \rvert / \Delta T \cdot 0.48 \cdot ACH^{0.8} \right)^6 \right]^{1/6}$
Ceiling	$T_s > T_{air}$	$0.704 \cdot \Delta T^{0.133} / D_h^{0.601}$
	CC panel	$2.12 \cdot \Delta T^{033}$
	$T_s < T_{air}$	$2.175 \cdot \Delta T^{0.308} / D_h^{0.076}$
Walls		$1.823 \cdot \Delta T^{0.293} / D_h^{0.121}$

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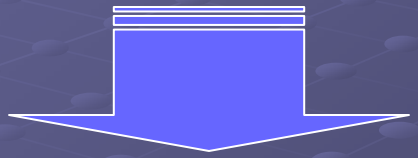
Summary

- The following CFD parameters were investigated:
  - grid resolution
  - convective to total heat flux ratio from human simulator

"Critical Simulation Parameters for Accurate CFD Predictions of Contaminant Dispersion from Indoor Point Sources," Annals of Occupational Hygiene

Conclusions

- Steady state simulations vs. Real buildings



- Dynamic simulations
  - Particularly appropriate for contaminant simulations
  - Use simple human simulators (manikins), but
  - Accurately determine boundary conditions
    - Heat transfer coefficients

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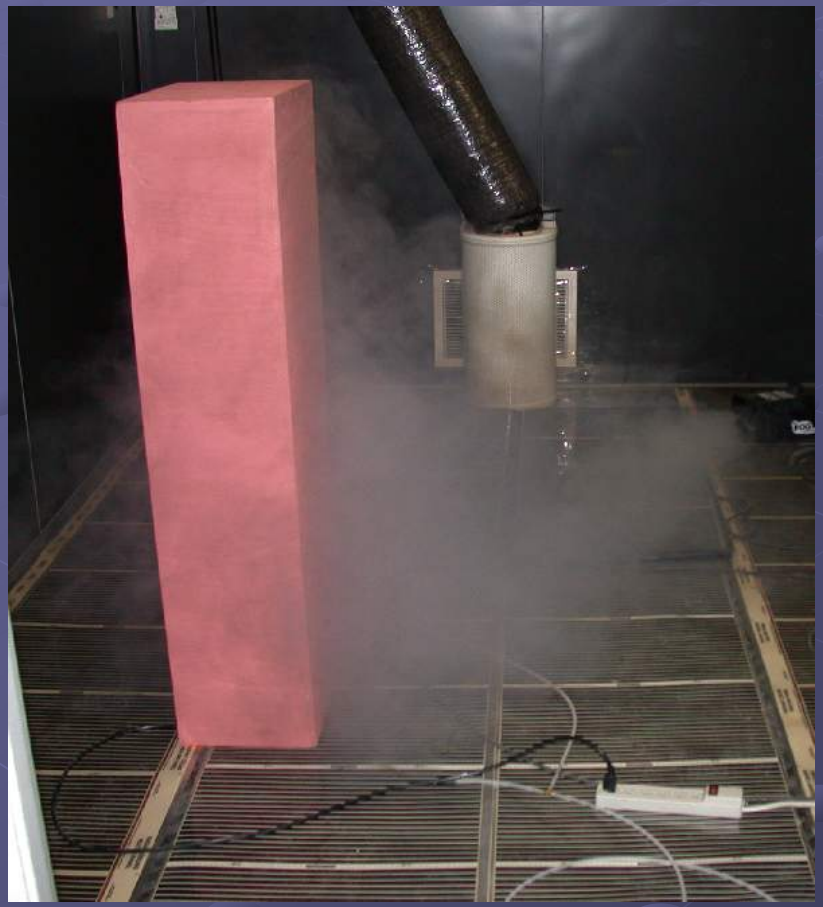
Flow visualization



V, T, and C measurements

Questions?

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