Modelling Thermal-Physiological Responses using CFD

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CIBSE Building Simulation Group

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ANSYS

Universität Stuttgart Germany

DTU

EPSRC Engineering and Physical Sciences Research Council

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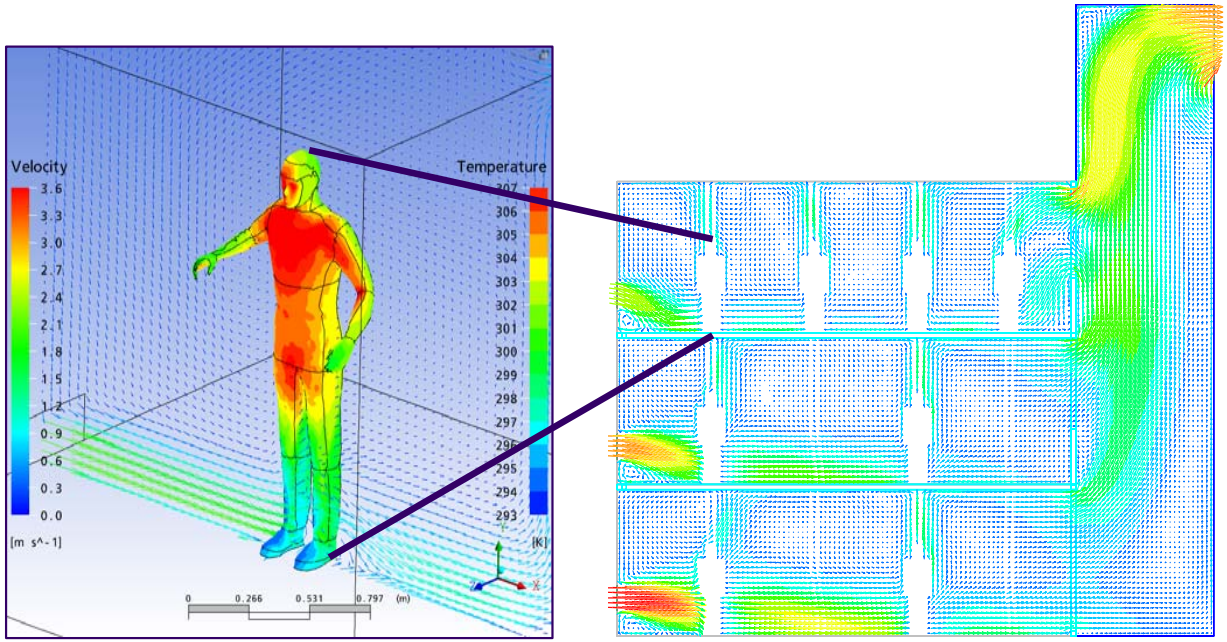
Presentation Content

- Project background
- The thermal-physiological model
- The CFD model
- Coupling technology
- Coupled simulation system demonstration
- Natural ventilation application
- Future work

Project Background

- Aim: *to develop a validated simulation system capable of predicting impact of natural ventilation designs on occupants and vice versa*



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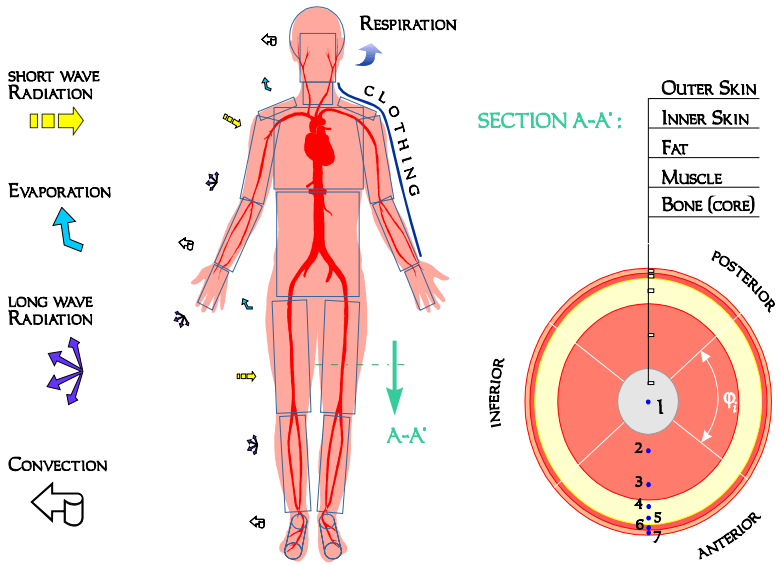
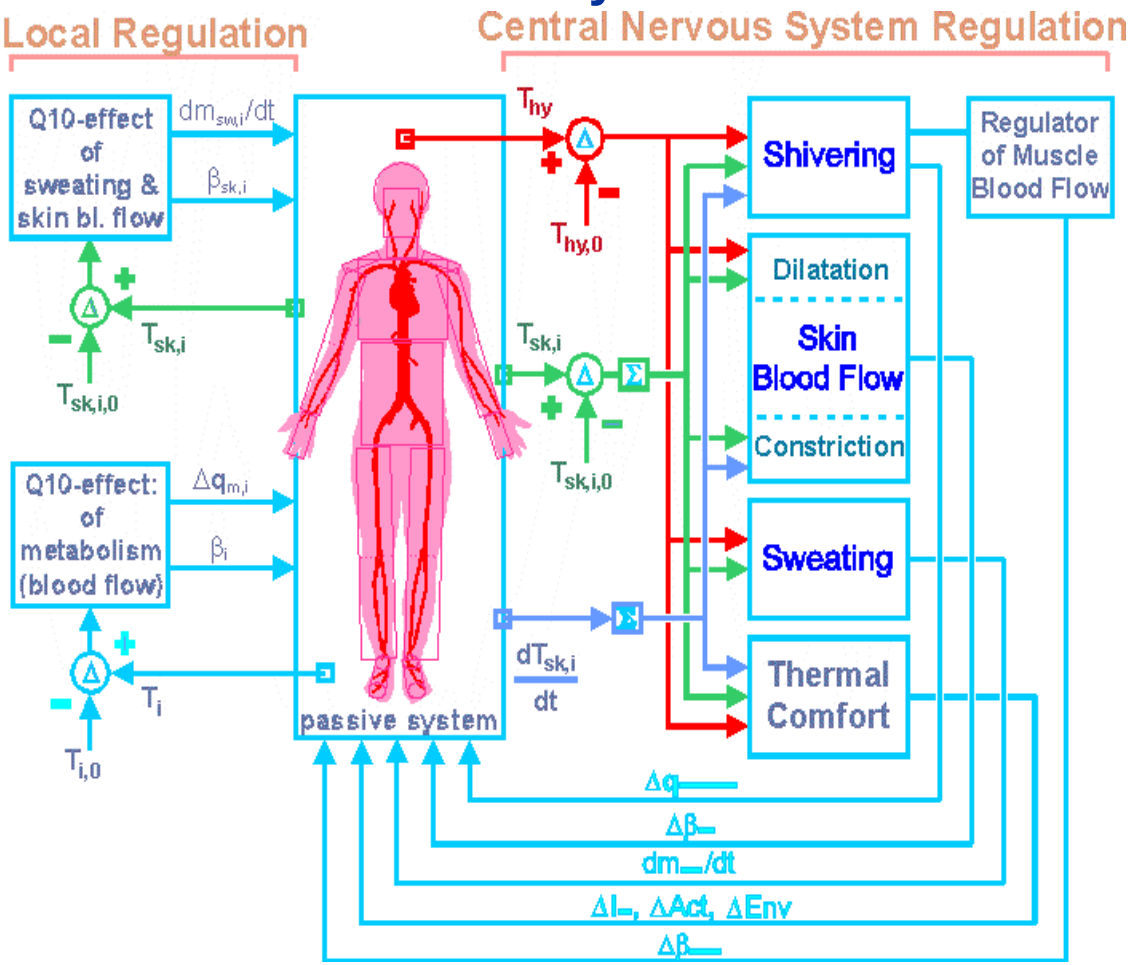
IESD-Fiala Human Thermal Comfort Model

Passive System



Active System



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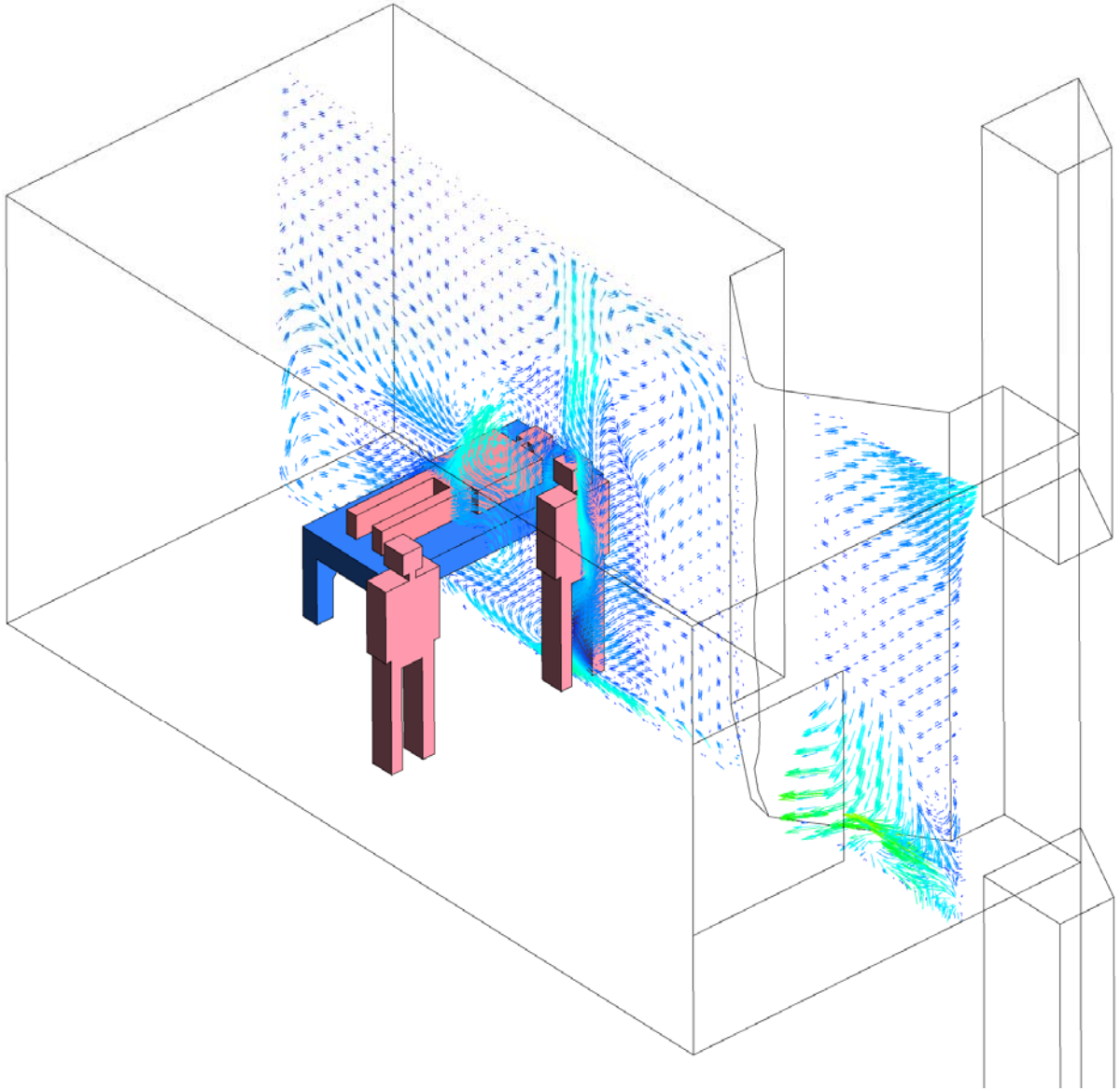
Computational Fluid Dynamics (CFD)

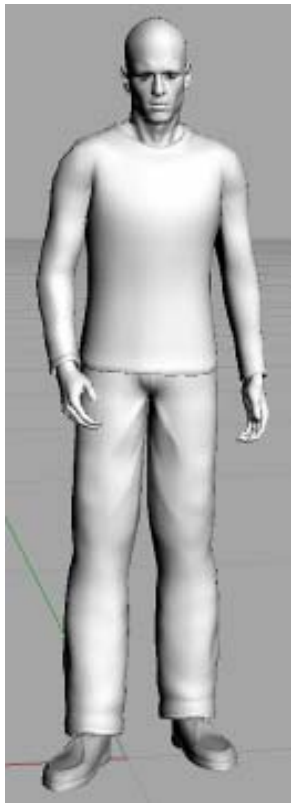


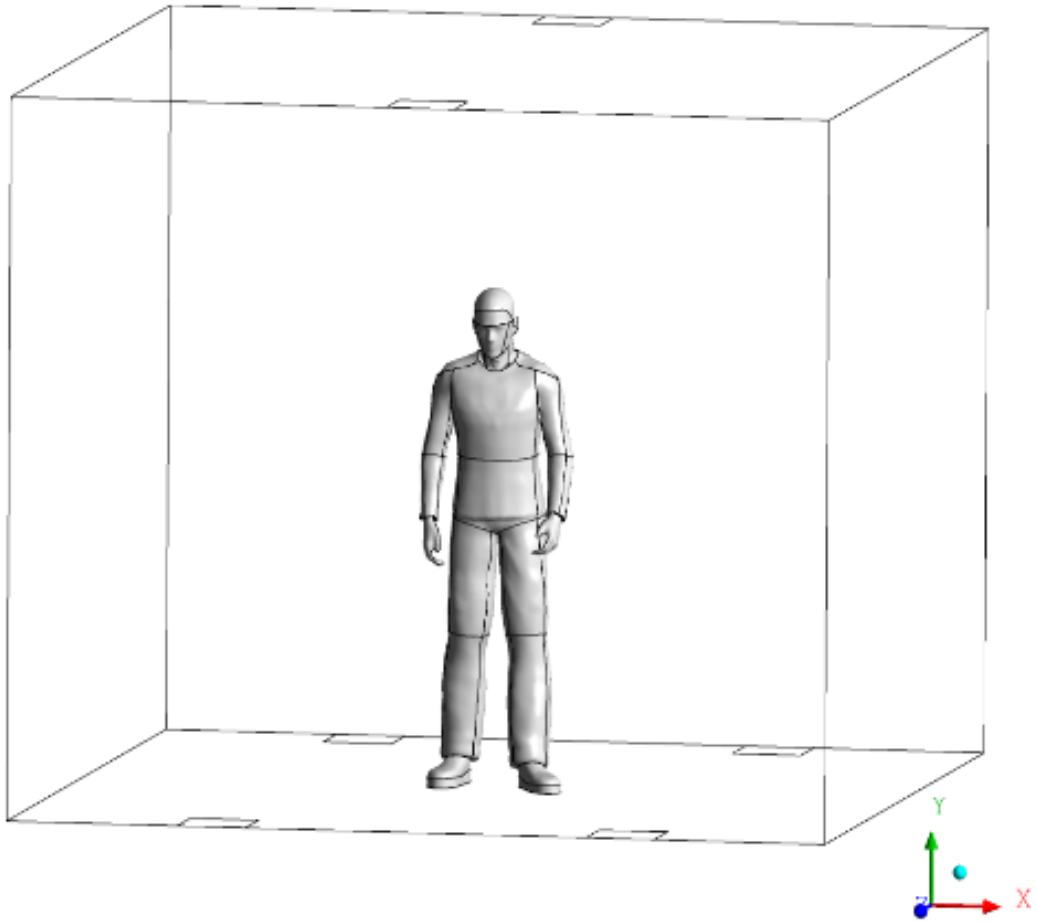
PMV

PPD

DTS

Computational Manikins





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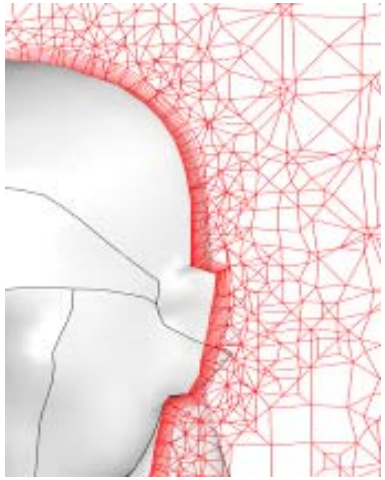
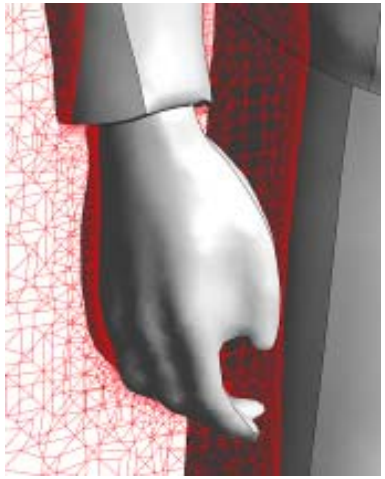
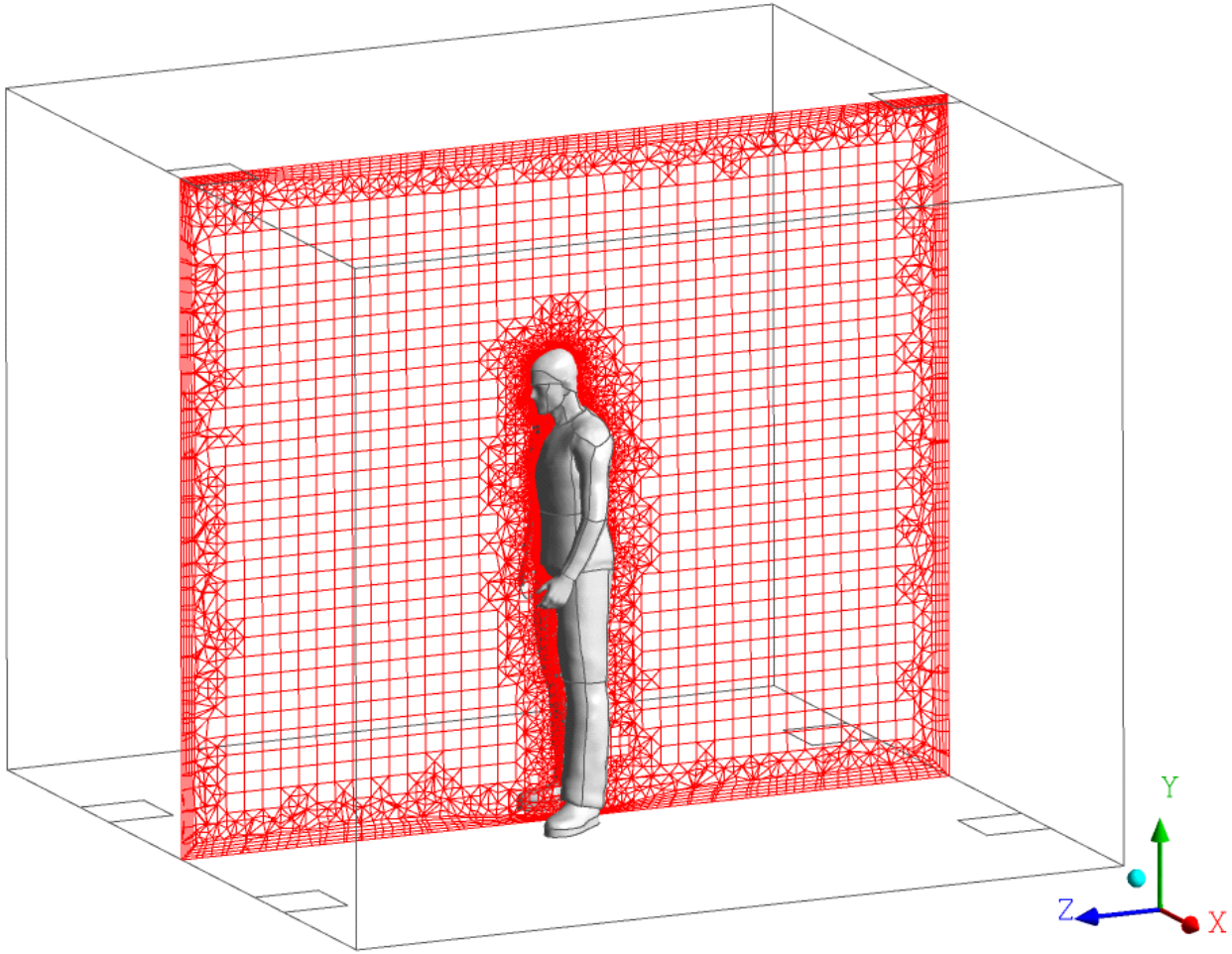
The Manikin in a CFD Environment







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ANSYS CFX - Customisation

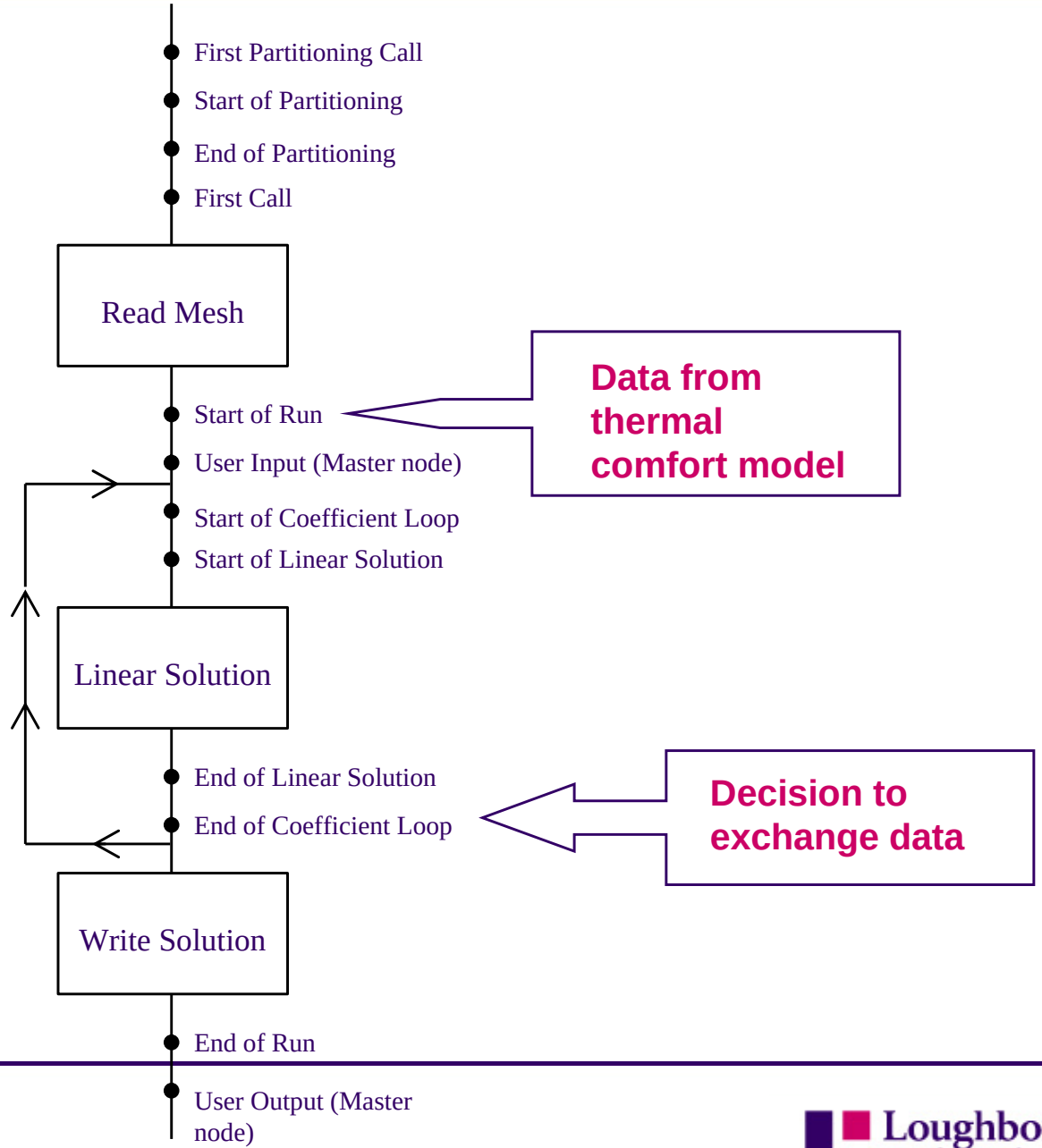
- Chosen CFD solver is ANSYS CFX
  - Powerful Application Program Interface (API)
  - Enables customisation of the solver solution cycle

- CFX can be customised using
  - CFX Command Language (CCL)
  - CFX Expression Language (CEL)
  - Embedded Perl
  - User Fortran

ANSYS CFX - User Fortran

- Two types of user Fortran
  - User CEL (user written CEL functions)
  - Junction Box (subroutines called at specific points in the solver execution cycle)
- Both are Fortran subroutines
- Both have access to all solver data structures
- User subroutines may, in turn call:
  - other user written subroutines
  - any solver subroutine or function

CFD Solver Events



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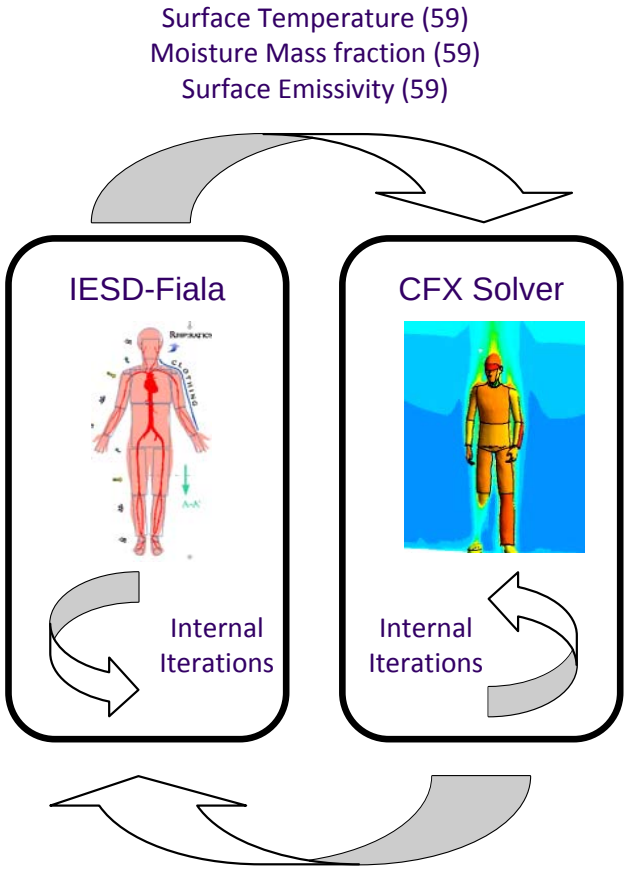
Data Exchange



Exchange data while
10-3 > RMS > 10-4

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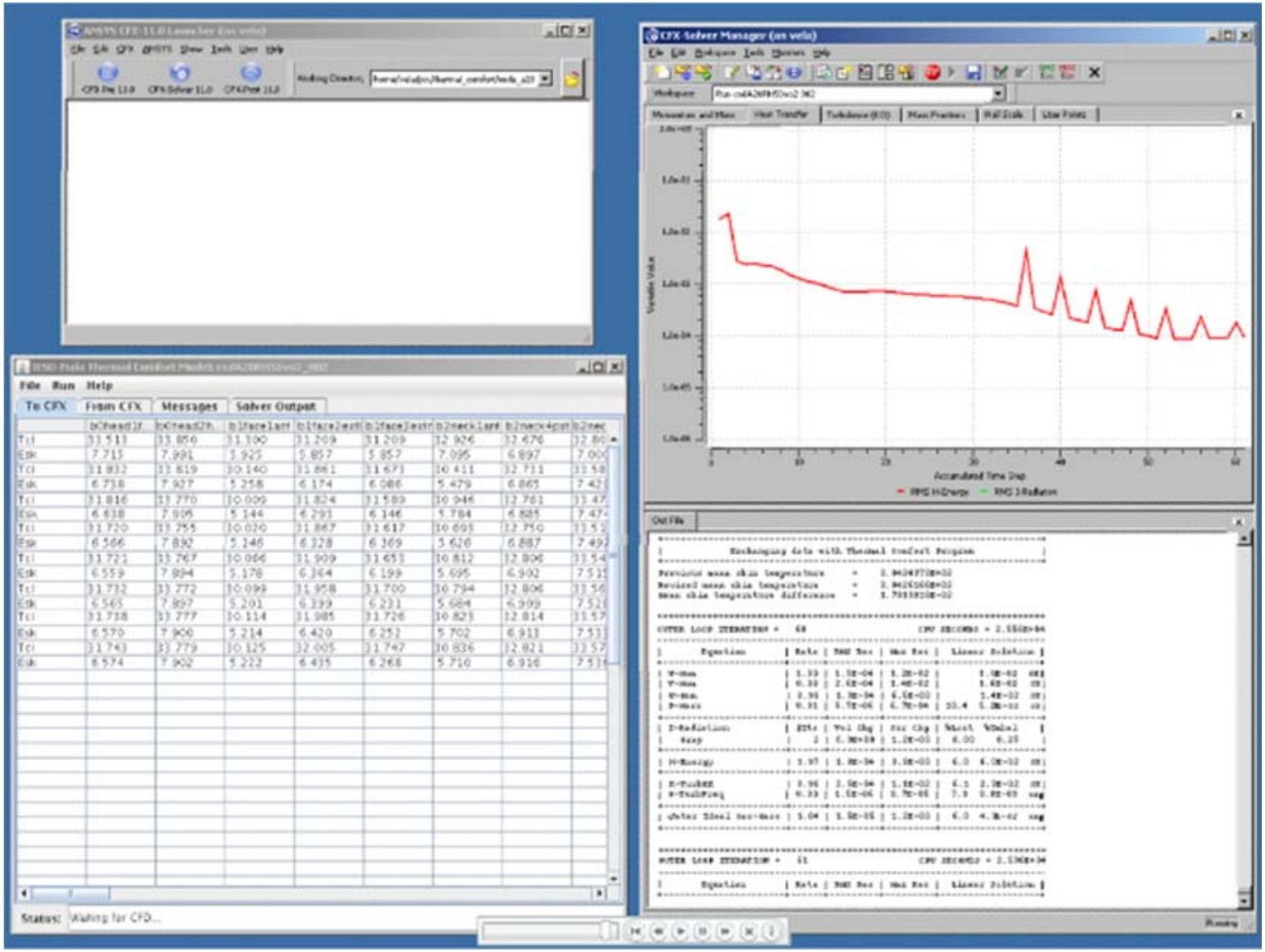
The Coupled System Demo



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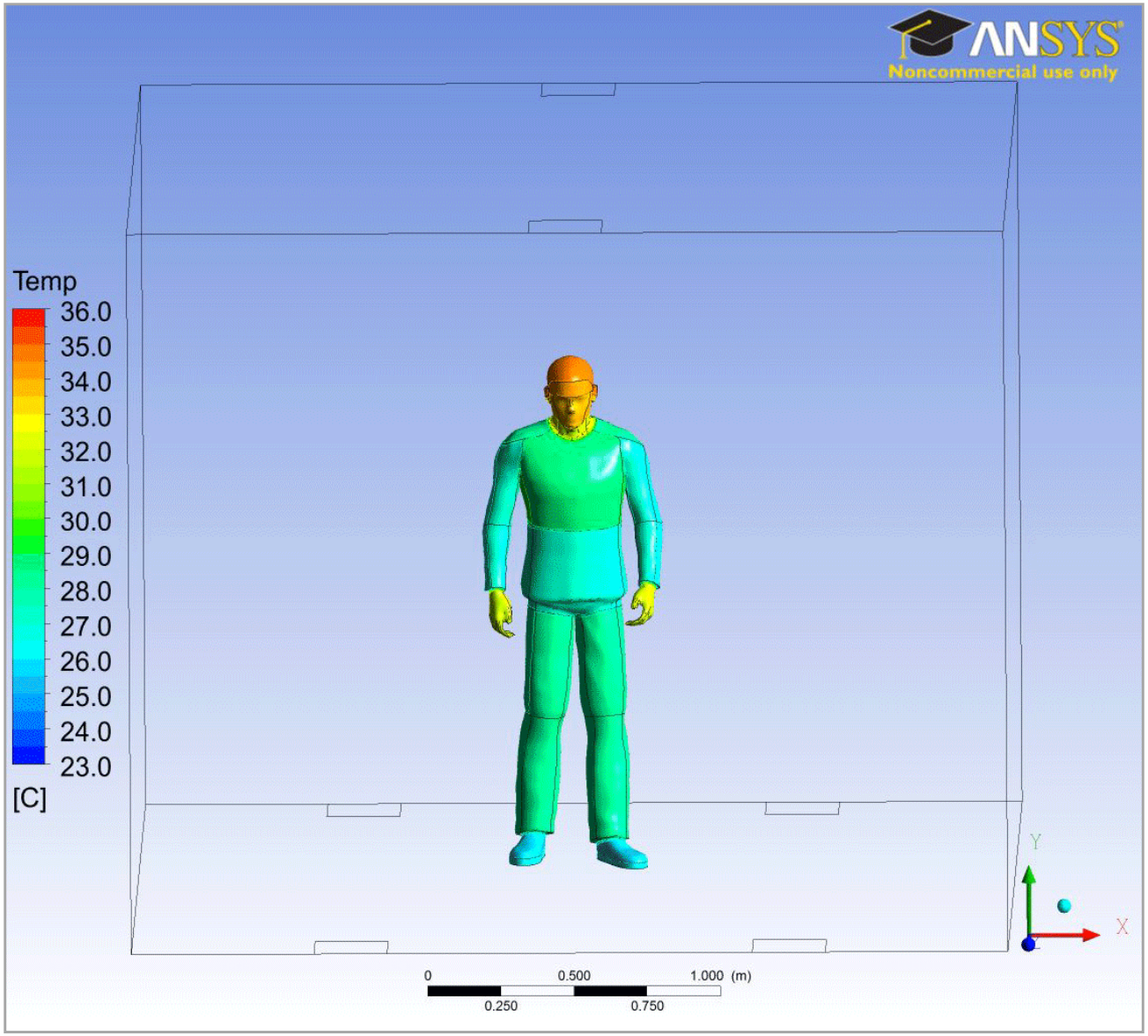
Coupled System Convergence



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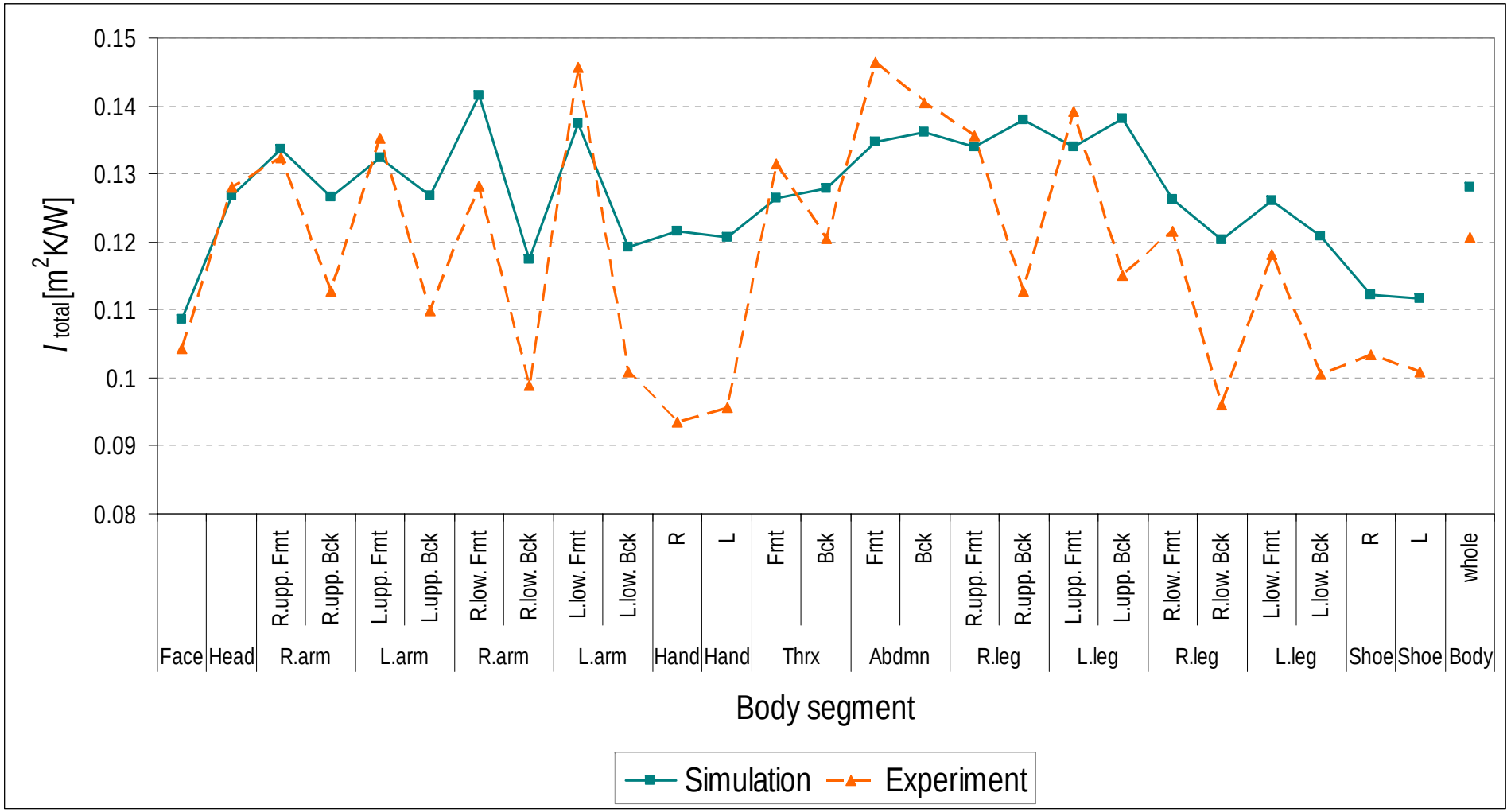
Validation: nude case



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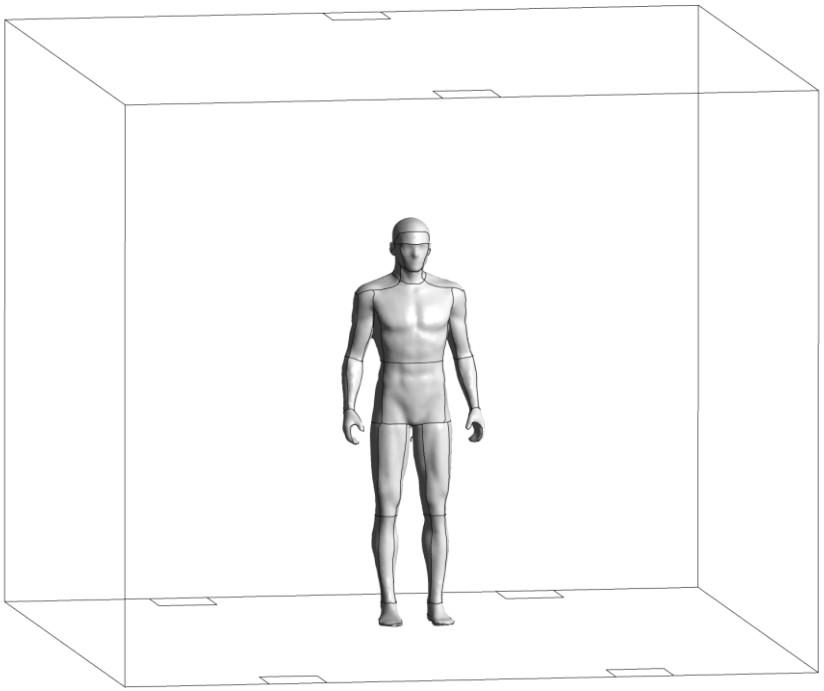
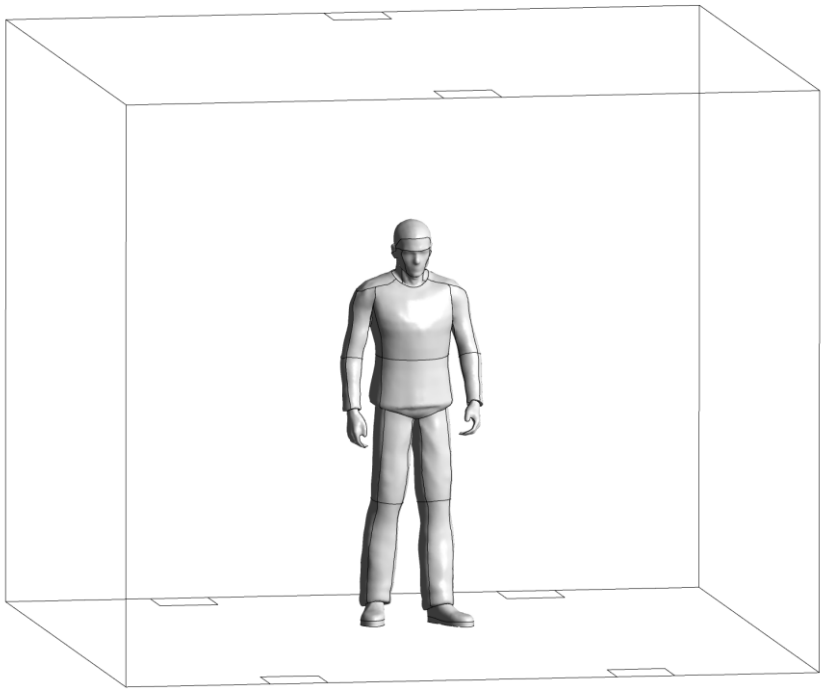
Natural Ventilation Case Study



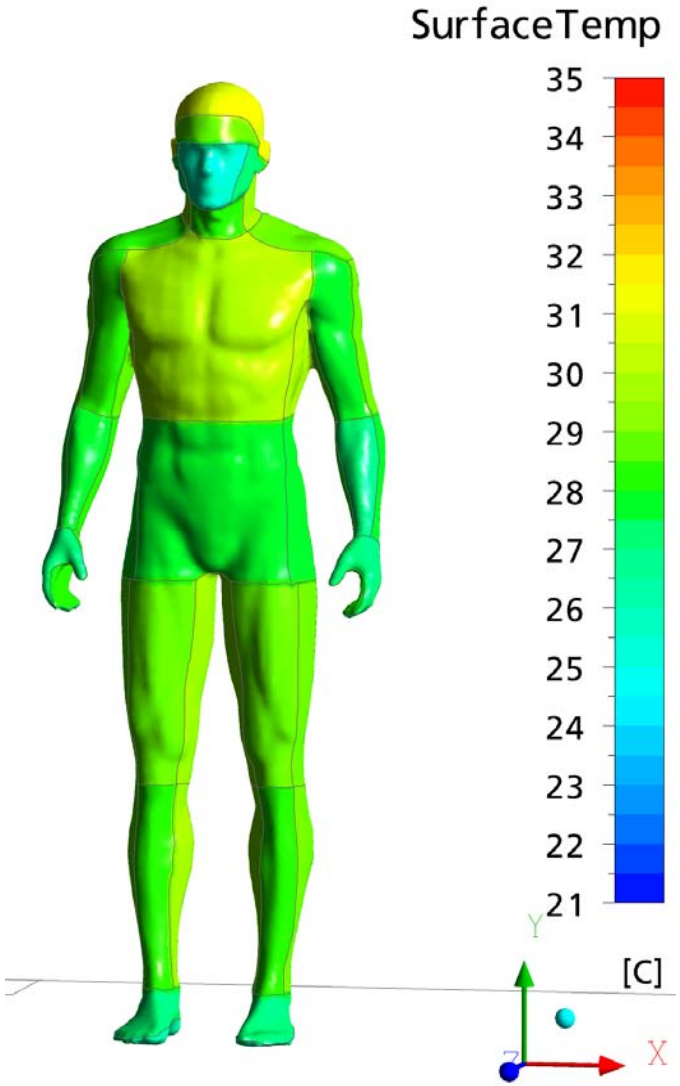


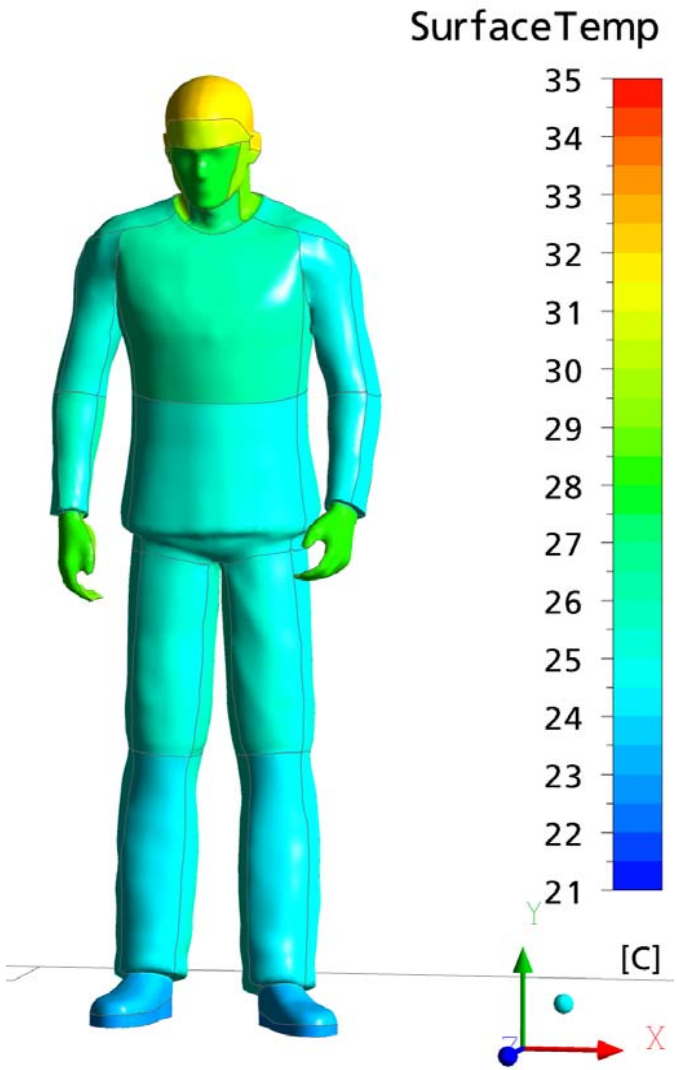
- Room (3m×3m×2.5m)
- Vent (0.25m×0.25m)
- Manikin
  - located in the centre
  - placed 0.06m above the floor

- Manikin 1.74m, 66kg
- 1.79m^2 (nude)
- 2.11 m^2 (clothed)
- fcl* = 1+0.305×Icl = 1.18
- Icl = 0.6 clo

* I Holmer, H Nilsson, G Havenith, KC Parsons (1999) Clothing convective heat exchange - proposal for improved prediction in standards and models, *Annals of Occupational Hygiene vol 43 number 5, pp 329-337*

Natural Ventilation Case Study: Results [Tair =21°C RH=40%]





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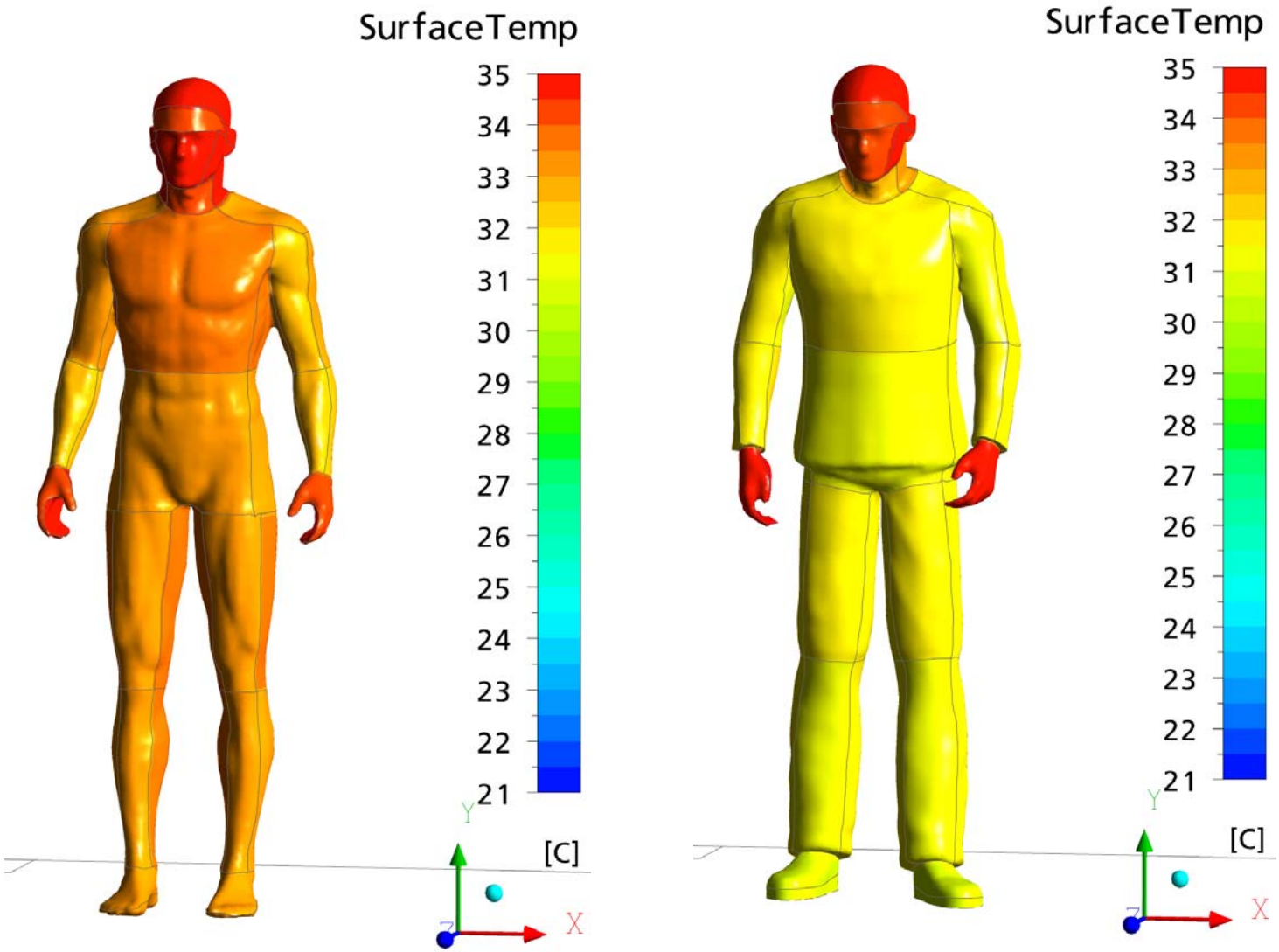
Natural Ventilation Case Study: Results [new – Tair =30°C RH=40%]



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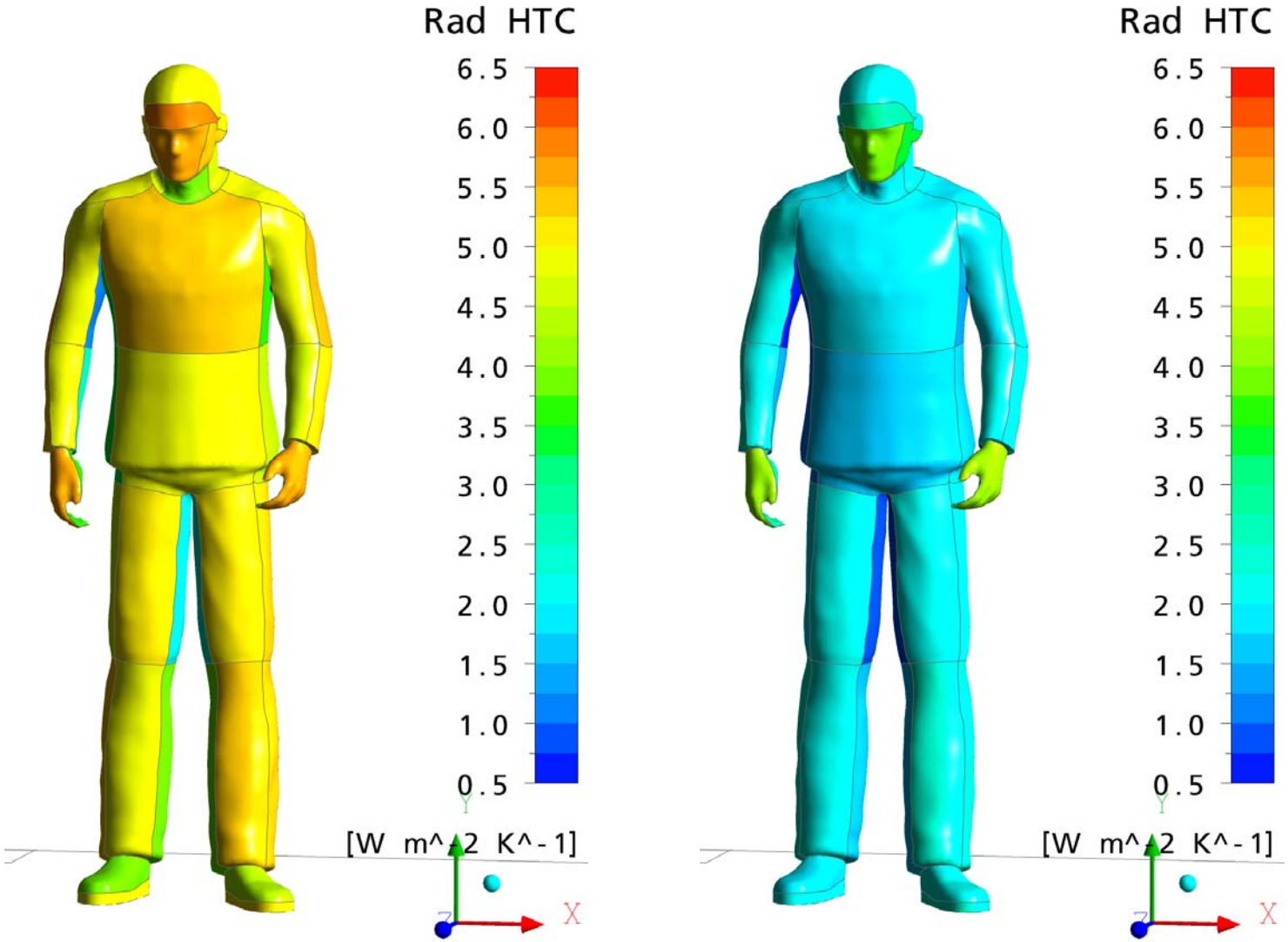
Natural Ventilation Case Study: Results
Radiative htc [T21clo vs T30clo]



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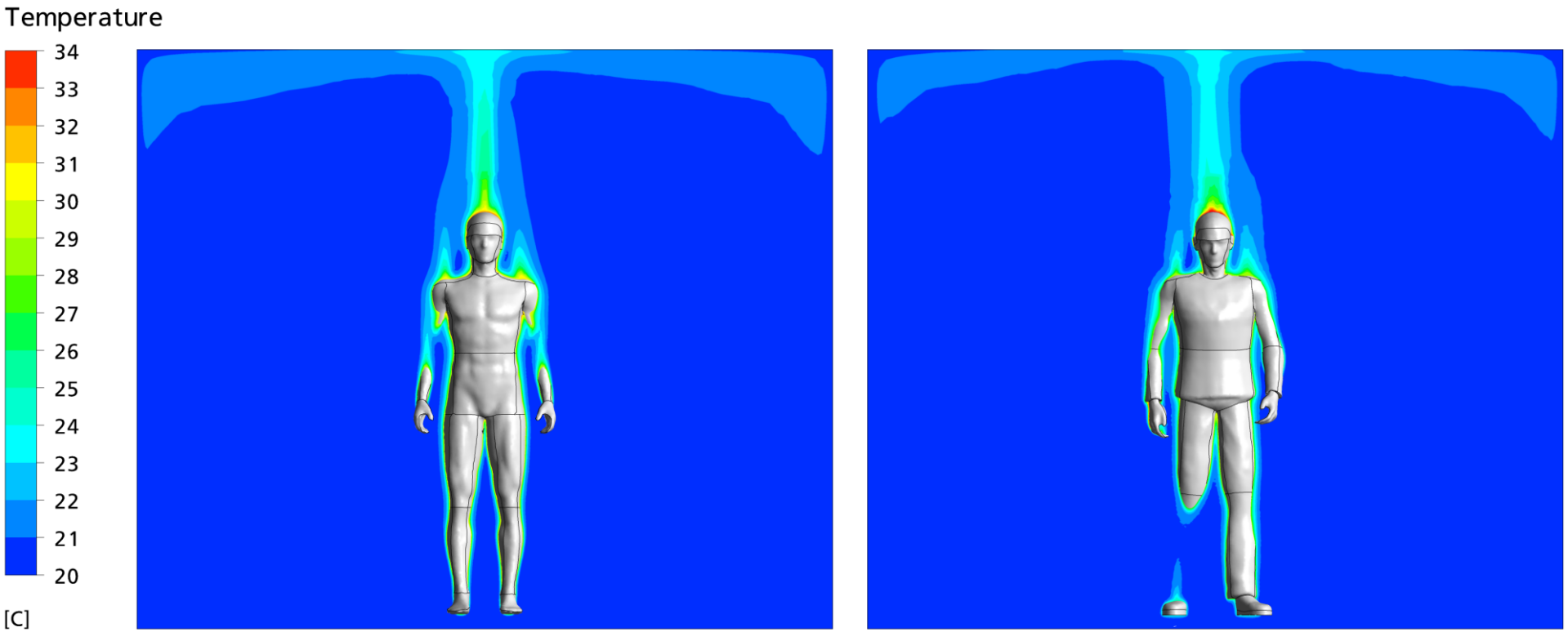
Temperature

Nude

Clothed



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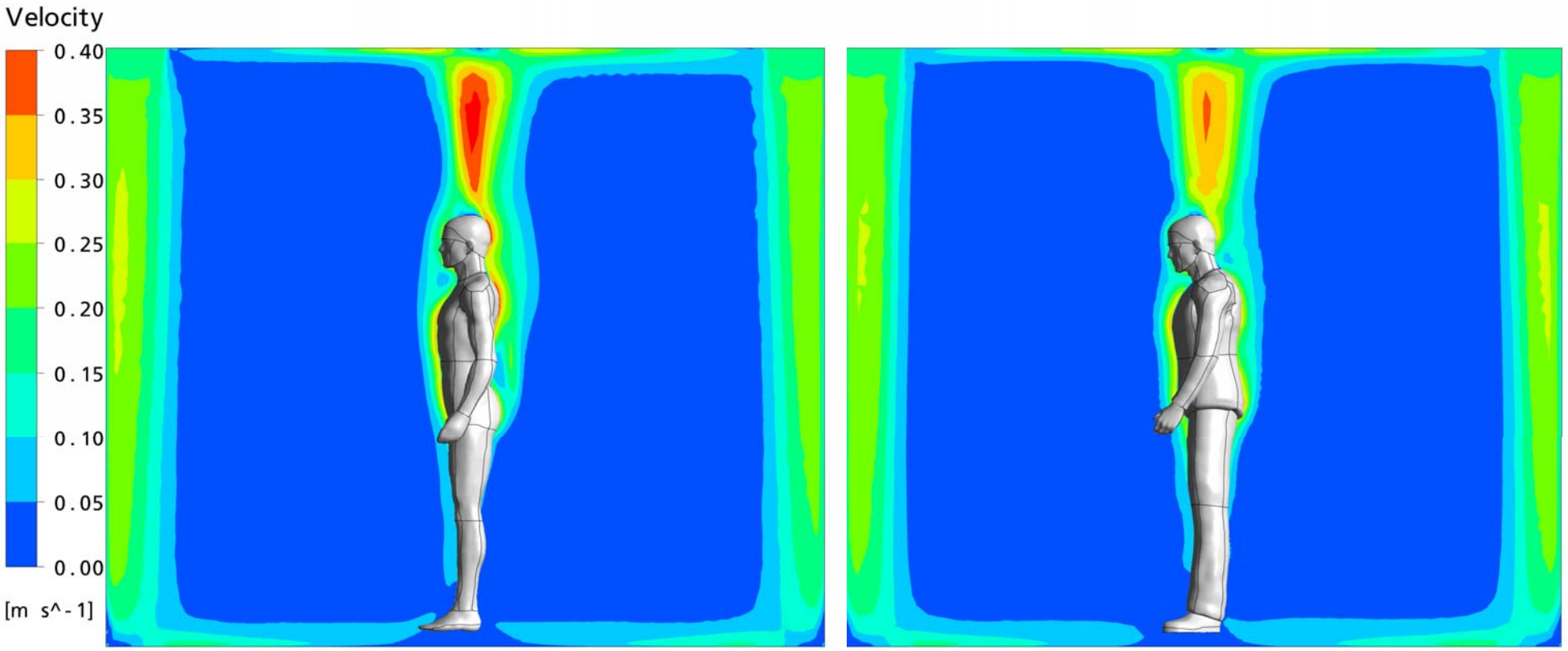
Air speed

Nude

Clothed



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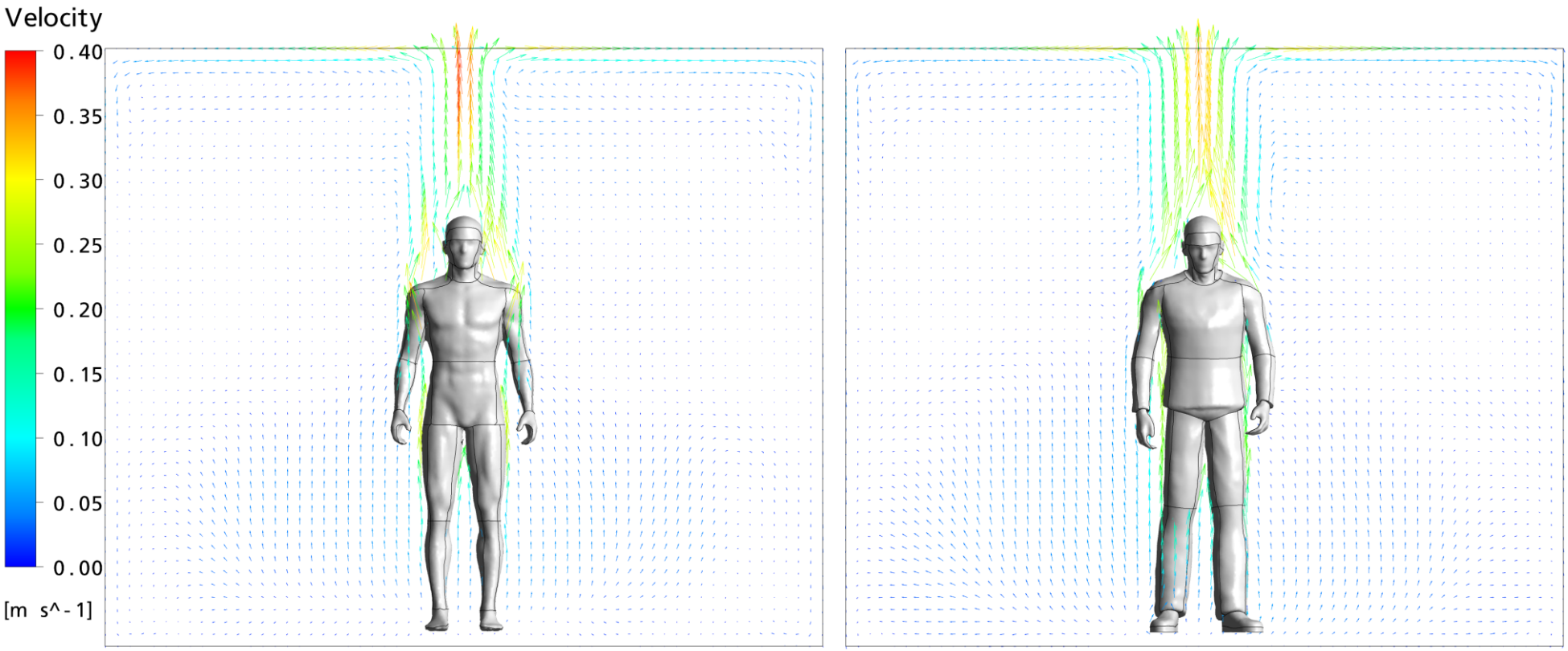
Velocity

Nude

Clothed



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Future Work

- Continued Validation
- Asymmetric radiation
- Ceiling radiant cooling
- Breathing manikins and IAQ
- Moving meshes

Acknowledgements

- EPSRC: Grant Ref. EP/C517520/2
- Mr Chris Staples and Dr Yehuda Sinai (Ansys UK)